Fall 2014
Volume 28, Issue 4 | ISSN 1069-2010

The Shot Peener

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

Take Note:
EI has improved the ALMEN strip

PLUS: THE FUTURE OF CLEANING AND PEENING ▮ THE IMPORTANCE OF ALMEN STRIP COVERAGE ▮ QUANTIFICATION OF SHOT PEENING COVERAGE

Coverage Measurement Device

*PC is not included

Easy USB connection to your PC

*Device image

COVERAGE CHECKER

Coverage Measurement Device

COVERAGE CHECKER

COVERAGE CHECKER the device for easy and precise coverage measurement

- Automated coverage inspection eliminates human error
- Multiple operators will get consistent results
- Beginners can measure coverage as skillfully as experienced operators
- COVERAGE CHECKER measures coverage in coil spring bores and other narrow areas
- A nozzle is available to measure coverage in the interior walls of holes
- With the addition of the focus adjustment attachment, COVERAGE CHECKER easily measures curved surfaces
- USB connection to your PC (USB cable is included)
- Compatible with Windows XP (32 bit) and Windows 7 (32 bit)

※Specifications of this device may be changed without notification.

Distributor

Country	Company	TEL	E-MAIL
USA	Electronics Inc.	+1 574-256-5001	sales@electronics-inc.com
CANADA	Shockform Inc.	+1 450-430-8000	sales@shockform.com
EUROPE	SONATS	+33 251-700-494	sonats@sonats-et.com

TOYO SEIKO CO.,LTD.
World Leading Company for Shot Peening

TEL:+81-567-52-3451 FAX:+81-567-52-3457
toyo@toyoseiko.co.jp
http://www.toyoseiko.co.jp

Industry News

THE SHOT PEENER

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

Six Things I Learned While Working on This Shot Peener

JACK CHAMPAIGNE

ONE OF THE BEST THINGS about publishing *The Shot Peener* is that I get a big picture view of our industry. Here are a few things that were particularly interesting to me in this issue of the magazine.

1. Progressive Surface continues to be a world leader in aerospace shot peening solutions and is a major contributor to the growth of shot peening in Singapore. We got to see firsthand their machines for a Singapore OEM and they are very impressive. EI is pleased that Progressive Surface has chosen the 700-24 MagnaValve as the non-ferrous valve for these machines.

2. Two of our best authorities on shot peening can tackle an often confusing topic — coverage and its relationship to Almen strips — from completely different angles and convincingly prove their point. Dr. John Cammett's approach is practical and supported by lab testing by EI's own Jeff Derda. Dr. David Kirk's approach is academic and supported with thorough equations and graphs. Both articles are good reads.

3. Our markets are more global than ever as shown by the announcements in our magazine. Sinto has purchased a company in Connecticut, Toyo Seiko has opened an office in Indiana, and Rösler dedicated a new manufacturing facility in Pune, India. To me, these are symbolic of a vibrant, growing industry and we offer our best wishes for great success in these new endeavors.

4. Equipment OEMs are actively researching and developing high-tech machines that will reduce a low-tech problem: maintenance. You'll enjoy Kumar Balan's article on the future of shot peening and blast cleaning and a review of how we got to where we are today.

5. Erwan Henry states the case for investing in new equipment as a way to reduce media costs and the overall importance of shot-blasting machines to the productivity of the surface preparation industry. His observation that shot blasting facilities see a drop in abrasive costs when they expand into new markets and purchase new machines ties in nicely with Kumar Balan's thoughts on continual improvement.

6. The Spring Manufacturers Institute (SMI) is launching a SMI Metal Engineering eXpo™ at the Charlotte Convention Center in Charlotte, North Carolina. The inaugural event for the engineered spring and precision metal components industries will take place October 20-22, 2015. If you're a supplier to the spring industry, you should consider exhibiting or attending the expo.

THE SHOT PEENER

Editor
Jack Champaigne

Associate Editor
Kathy Levy

Publisher
Electronics Inc.

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

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

The Secret to Maximizing Productivity

PREVENTATIVE MAINTENANCE

Maximizing Productivity

It is important to ensure that your equipment is properly maintained and that you have the right parts in stock to ensure that you are ready for any potential situation.

Preventative maintenance programs and trending your machine maintenance keeps "down time" to a minimum.

"Preventative effort becomes Predictive result"

Service & Maintenance

Langtry Blast Technologies Inc. (LBTI) host a large line of "Machine Tune-Up" and "Preventative Maintenance" plans, as well as the ability to work with you to find your custom maintenance needs.

These plans help create "scheduled down time" blocks and hence, use predictive maintenance to ensure that both your equipment and production is dependable.

Let Us Show You How

Langtry Blast Technologies Inc. (LBTI) recognizes the need to keep production costs at a minimum in the present economic climate.

This is why LBTI focuses considerable effort towards preventative maintenance and constant health checks for your existing equipment.

Your equipment is not a consumable and you should not treat it as such.

Langtry
Blast Technologies Inc.

Visit us online: **www.blastech.org**
Email: **info@blastech.org**
Ph: (1) 905 681 2030 Fax: (1) 905 681 2814

ITAR

BURLINGTON Chamber of Commerce

Introducing the New EI Double-Sided Numbered Almen Strip

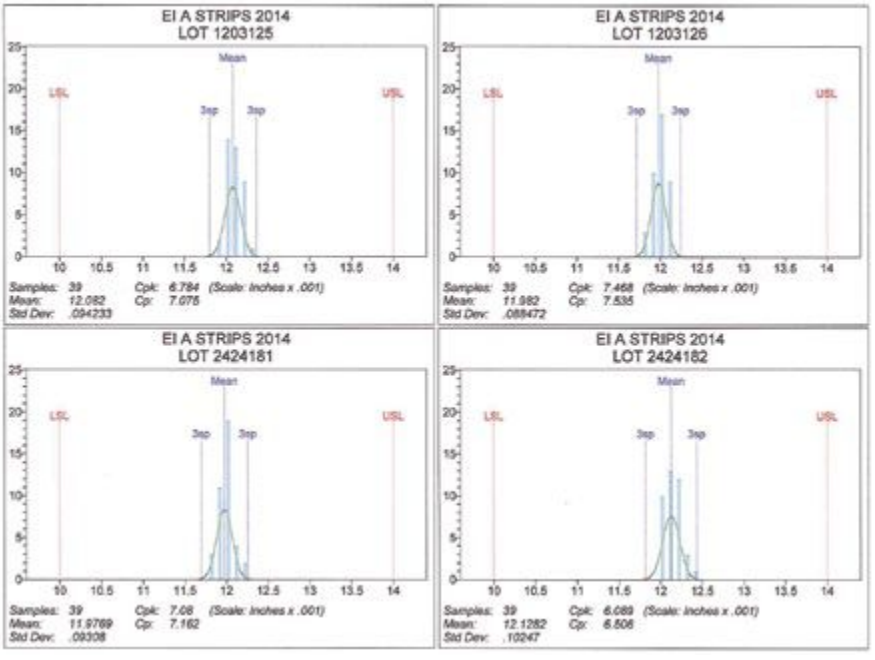
ELECTRONICS INC. has added a new feature to their Numbered Almen Strips with Coverage Check Finish: The lot number is printed at the top of both sides of the strip. This innovation ensures that you always have a legible lot number and plenty of room to add your own notes. Typical notes on the strips include print numbers, procedure numbers, the date and the arc height reading.

"Recordkeeping is part of a validated shot peening process and our new double-sided numbered Almen strip will help our customers document a controlled shot peening process," said Tom Brickley, Vice President at Electronics Inc.

Below the Surface of an EI Almen Strip

The benefits of an EI Almen strip go deeper than a numbering system and polished finish: EI Almen strips are inspected in compliance with SAE standards which requires the use of the #2 Almen gage for pre-bow measurements. Any other measuring system, such as a laser measurement, does not meet the requirements of SAE J 442 or AMS 2430. Laboratory tests have shown significant inconsistencies with strips measured with laser equipment.

In addition to a tightly controlled manufacturing process and specification compliance testing, EI verifies that their strips are consistent in thickness, flatness and hardness. The histograms to the right prove that strips from different lots will perform consistently. EI has been conducting consistency tests since 2007; the year they began manufacturing their own strips. EI welcomes inquiries on their Almen strip specification compliance program and performance tests. For more information, please call 1-800-832-5653 (USA and Canada) or 1-574-256-5001.



The EI 2014 Almen Strip Performance testing program verifies that the strips will perform consistently from lot to lot.

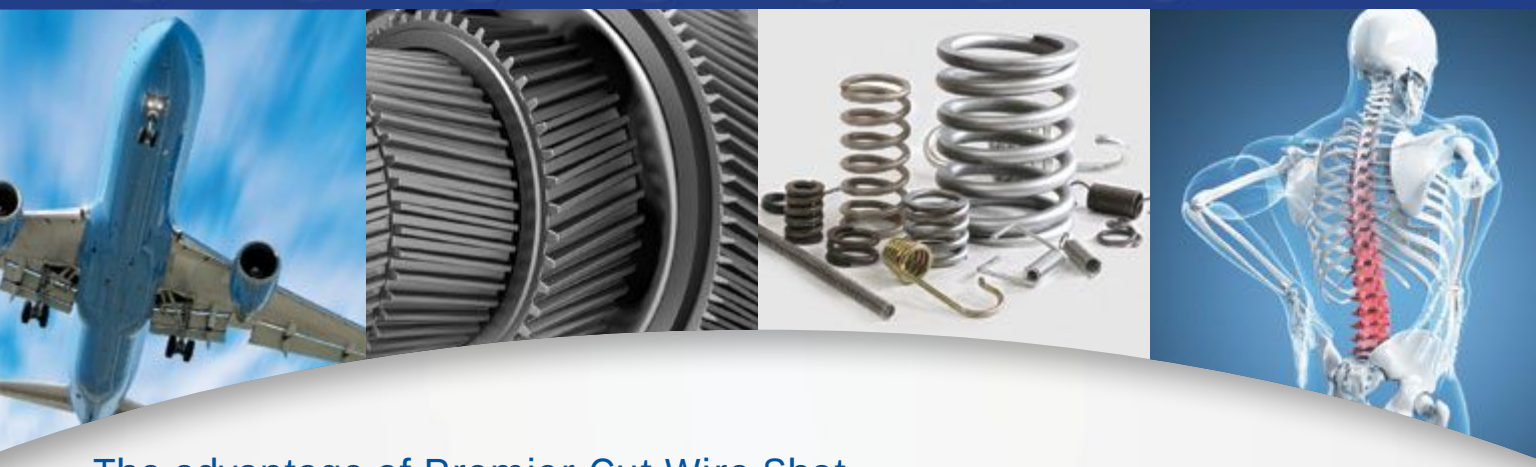
The new Electronics Inc. Double-Sided Numbered Almen strips are available at the same price as the current EI strips. For more information and to order, call 1-800-832-5653 (USA and Canada) or 1-574-256-5001.

PREMIER

PREMIER SHOT COMPANY

1666 Enterprise Parkway Twinsburg, OH 44087

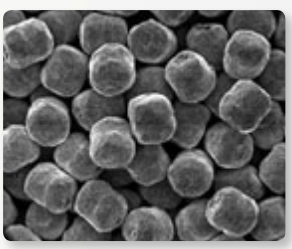
A Cut Above



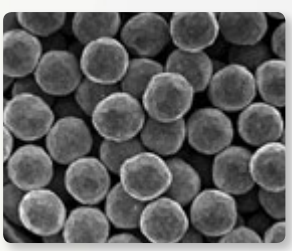
The advantage of Premier Cut Wire Shot

- **Highest Durability** Due to its wrought internal structure with almost no internal defects (cracks, porosity, shrinkage, etc.) the durability of Premier Cut Wire Shot can be many times that of other commonly used peening media
- **Improved Consistency** Highest consistency from particle to particle in size, shape, hardness and density compared to commonly used metallic media.
- **Highest Resistance to Fracture** Premier Cut Wire Shot media tends to wear down and become smaller in size rather than fracturing into sharp-edged broken particles, which may cause surface damage to the part.
- **Lower Dust Generation** Highest durability equals lowest dust levels.
- **Lower Surface Contamination** Cut Wire Shot doesn't have an Iron Oxide coating or leave Iron Oxide residue — parts are cleaner and brighter.
- **Improved Part Life** Parts exhibit higher and more consistent life than those peened with equivalent size and hardness cast steel shot.
- **Substantial Cost Savings** The increase in useful life of Premier Cut Wire Shot results in savings in media consumption and reclamation, dust removal and containment, surface contamination and equipment maintenance.

As Cut



Normal Conditioning



Special Conditioning

Premier Shot Cut Wire Products for

Automotive ● Medical

Aerospace Applications Worldwide

(330) 405-0583

1666 Enterprise Parkway,
Twinsburg, Ohio 44087

premiershot.com

Progressive Surface Delivers Turnkey Operation

WHEN AN AEROSPACE OEM in Singapore wanted robotic shot peening machines with turnkey operation, they came to their trusted resource: Progressive Surface. The OEM required three identical machines for the shot peening of aircraft fan blades. The part programs needed to run in any of the three machines and the dimensional stability of the parts was crucial. The fan blade airfoils could not twist out of shape after peening. "We believe the customer entrusted us with the project because they have a long history with our robotic machines and we can support them through our multiple locations in Singapore," said Bill Barker, Sales Engineer with Progressive Surface.

As mentioned, the machines are identical and the specifications and their benefits are as follows:

- Ceiling-mounted Fanuc M20i robot and turntable that is an auxiliary axis to the robot
- Single blast nozzle for root peening and a two-nozzle system for peening airfoils
- Sweco vibratory screening system to screen out broken shot particles and undersized media
- Dual-pressure pot blast system that provides a continuous supply of media
- Closed-loop controlled air pressure and media flow rates
- Saint Gobain Zirshot zirconia media for optimum surface finish control while meeting the low intensity requirements
- PRIMS Pro computer operator interface by Progressive Surface for intuitive part program selection, complete process monitoring and extensive datalogging
- Electronics Inc. 700-24 MagnaValves for non-ferrous media

The 700-24 MagnaValve is a new product and this is its first implementation on a Progressive Surface machine. "The decision to use a different media control method was difficult for us to make," said Mr. Barker, "but in the end, it was the correct decision. In the past, we used an Electronics Inc. NFS-100 non-ferrous flow sensor with our servo-controlled

Two of these identical machines have been shipped to an aerospace OEM in Singapore. The third remains at Progressive Surface for a short time for the development of a turnkey process for motion programs, Almen fixtures, and part-holding fixtures.

ONE GLOBAL SINTO

sinto

Peening Solutions For

AEROSPACE • AUTOMOTIVE • MEDICAL

POWER GENERATION

Now with Contract Peening Resources!

Accredited Nadcap Surface Enhancement

ISO 9001 : 2008
Certificate registration no. 10000231 QM08

Visit us at
Shot Peening Workshop
Booth #6
October 14-16, 2014
Orlando, Florida

sinto

New Harmony » New Solutions™

www.sinto.com

NATIONAL PEENING
SINTOKOGIO GROUP
Tel 800-325-7336
www.nationalpeening.com

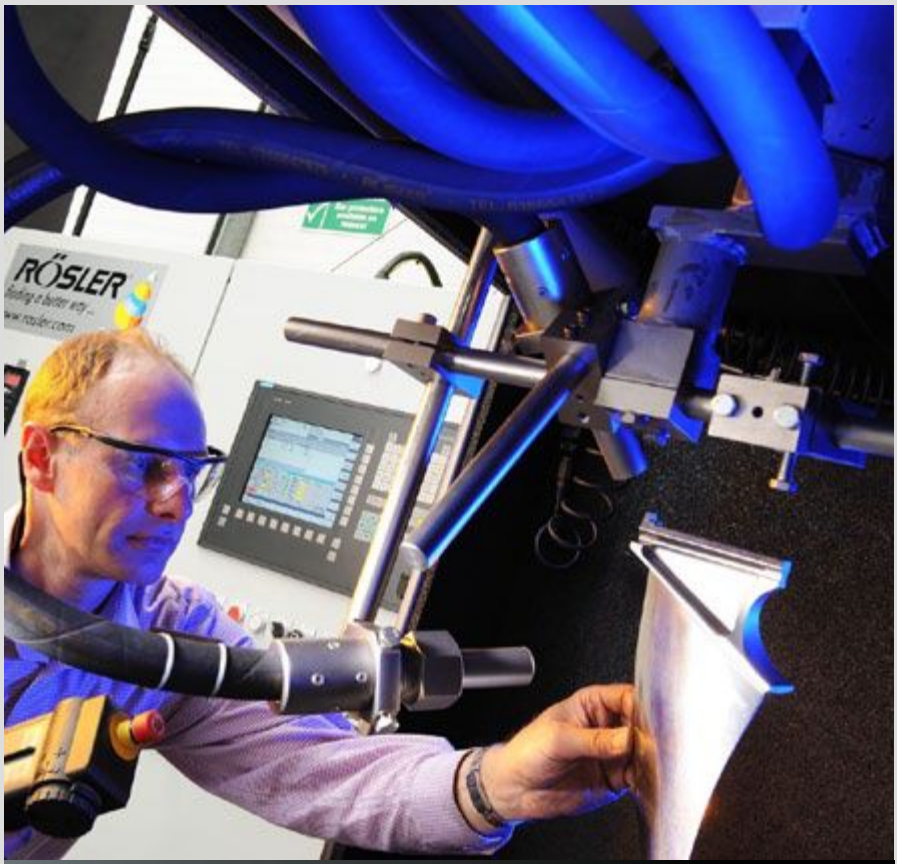
orifice for closed-loop media flow control. While this approach worked, it was quite tall and it had too many moving parts. The beauty of the 700-24 valve is that it uses the best attributes of the original ferrous MagnaValves and it uses the same style controller," he added.

James Hoffman, a Progressive Surface Process Engineer, noted, "This device has been very reliable up to this point in all our internal testing. The calibration procedure is very straight forward. After it is calibrated, the valve reaches its setpoint quickly when media flow is initiated and it is able to maintain a very consistent flow through the blasting cycle. To date, we have flowed several different types of non-ferrous media through the device without any issues and have had no problem maintaining our standard calibration tolerances."

Two of the machines have been shipped to the customer while one remains at Progressive Surface for process development. Due to Progressive's experience in peening many different types of fan blades and roots, the customer asked them to develop a turnkey process which included shot peening process parameters, robot motion programs, Almen fixtures, and part-holding fixtures. "Since the machines are identical, we were able to ship two of the machines to the customer site and hold the third machine at our facility for a short time to complete development of the process for a range of parts," said Mr. Barker.

"The project technical manager and the buyer both came to Progressive Surface for the machine runoffs. (A machine run-off is a collaborative effort between the customer and Progressive to test and approve the machine(s) prior to shipment.) They were pleased with the machines and looked forward to getting them into production," concluded Mr. Barker.

Each of the three Progressive Surface shot peening machines has two 700-24 MagnaValves for non-ferrous media.



Send us your challenge... Rosler can find a better way.

Rosler Metal Finishing USA, LLC is the leader in mass finishing, shot blasting, automated processes and media - made in the USA.

RÖSLER finding a better way ...

Visit www.rosler.us or call 269-441-3000.

JVS - Vertical Structure Monorail System

- Customizable vertical structure includes up to 12 wheels for consistent, even coverage
- Cleans all surfaces in one pass through 36”x84” cleaning envelope
- Optional fittings include PLC controlled VFD, magna-valves and rust inhibitor applications
- Monorail fitted with up to 37 fixtures accommodating 2-8 parts each

RMT - Multi-Tumbler Machine

- Batch sizes from 3 to 35 cubic feet
- No machine pinch points to trap or damage small parts
- Easily automated into process lines
- Highly successful applications include shot peening springs, fasteners, and chain components

RMBD - Tumble Belt Machines

- Unequaled flow through tumbling action
- Many machine configurations to suit varied intensity and coverage requirements
- Ideal for shot peening connecting rods, gears and other components where high volumes and gentle processing are required.

Visit www.rosler.us or call 269-441-3000.

RÖSLER finding a better way ...

by Kumar Balan | Director, Global Sales | Empire Abrasive Company

The Future of Cleaning and Peening

INTRODUCTION

How do you characterize an industry that has been active for over a century? Relatively uncomplicated and practical, the closely-related techniques of blast cleaning and shot peening have cleaned surfaces and enhanced the useful life of metallic components.

Even though the pace of technology growth in the surface preparation industry has been slower than related manufacturing sectors, shot peening and blast cleaning equipment is used extensively in advanced manufacturing processes. Aerospace, automotive, and medical devices have derived benefits from these surface treatments and advanced industries have played a major role in defining the accuracy and repeatability of the processes by developing specifications and audits. These sophisticated manufacturing sectors have also been the driving force for equipment manufacturers to innovate, grow and attempt to align with related industries.

Still, the unanimous opinion is that the growth rate should have been higher and faster. What were the deterrents? Mark Ziegler, a Foundry Specialist with The Profile Group in Wisconsin, works with professionals in one of the most intense production environments for blast equipment. He echoes a common theme when discussing the blast cleaning industry. "The lack of need for growth, price-sensitivity, reduced importance attached to the process and equipment maintenance are all part of the recurring theme," he said. He was also quick to point out, however, that the growth initiatives that did take place over the past 25 years have greatly enhanced productivity and continue to be widely embraced by its users.

The future can neither be static nor follow the pace of the last 25 years. There is fertile ground for the brightest and the best talent to innovate. Here exists tremendous potential and opportunities to take this technology to the next level. Rather than buying into the parochial beliefs of it heading towards low-cost production venues, diminishing profit margins and commodification of technology, it is our obligation to dig deeper into our individual expertise and structure the future.

This discussion will attempt to visualize the future of the blast cleaning and shot peening processes without the encumbrance of perceived limitations. We will trace some of the larger scale developments from the past that have taken the industry through quantum leaps and test their propensity to lead us into the future. Status quo is not acceptable and the risks associated with it are too many to mention and don't warrant space in our discussion.

HISTORY

The following list identifies major events in terms of their contribution towards technological growth and not necessarily by historical timeline.

- The first stream of blast media was propelled from a blast nozzle well over a century ago. This type of media propulsion continues to be popular in many applications. However, the invention of the blast wheel was a game changer of historic significance in our industry. With over ten times the media flow rate capabilities of blast nozzles, this 85+ year-old invention redefined productivity standards in many applications.

  Since then, the blast wheel has evolved into advanced designs, providing laminar flow patterns, increased velocity, reduced media consumption, and built with favorable metallurgical properties to optimize wear. Blast wheels are used in blast cleaning and shot peening alike. It is not uncommon to see modules of blast cabinets fitted with multiple blast wheels, cleaning hot rolled strips at over 150 feet per minute (over 45 mpm). Shipyards, steel plants, fabricators, foundries and several other sectors have benefited from this type of media propulsion technique because it fulfilled their need for speed and productivity. In the world of shot peening, wheelblast machines peen landing gear and large auto transmissions, to list a couple examples.

  Conscientious wheelblast equipment manufacturers continue to research the specific areas of wear-resistant material properties, ease of maintenance, monitoring of wear characteristics leading to predictive analyses, etc. When we further integrate control technology into our equipment, these initiatives show great promise for the future of blast wheels.

- Until about 20 years ago, the Programmable Logic Controller (PLC) was a revered option in shot peening

The new FLAPSPEED PRO®

Your TOP GUN Tool For Rotary Flapper Peening

Rugged Exterior with Wheels meets most Airline Carry-On Regulation

Custom Foam with cut outs for:
- Magnetic Block
- Handpiece Grinders 2X
- Magnifier Loupe
- Miscellaneous items
- Two Mandrels
- Almen Gage
- Wrenches
- Zero Block
- USB Key
- Flaps
- Almen Strips

Empty Weight of 21 lbs. (9.5 Kg)
Fully Loaded Weight of 27 lbs. (12.3 Kg)

Emergency Off Button

Small and Comfortable Handpiece Grinder

Grinder Cord of 25 ft. (7.7m)

USB Memory Key Slot to Record Process Parameters

Locking Military Type Connectors

Large 5.7 in. (145mm) QVGA Color Display with Robust Touch Screen Interface

Integrated Saturation Curve Solver Software

ON/OFF Button

Benefits of using the FlapSpeed PRO®

- The only dedicated tool for Rotary Flapper Peening
- Simple easy Kit includes everyting you need
- Meets all industry and company specifications
- Optimal speed maintained at all times
- Saves process data to USB key
- Improves process traceability and visibility
- Ensures reliable and repeatable peening

Now with an Integrated Saturation Curve Solver. No more Calculations!

SHOCKFORM

www.shockform.com

machines with an adoption rate of less than 10%. It was almost non-existent for cleaning applications. The myriad of wires inside a control panel was every programmer's nightmare, but they continued to tolerate it. Transformation came gradually. Accessibility in terms of price and the PLC's general acceptance within the industry changed the way cleaning and peening equipment manufacturers designed controls. Critical process parameters could then be monitored and controlled; the overall process could be fine-tuned and made repeatable. This also led to the development of graphic user interfaces, alarm screens, recipe creation, storage and retrieval. Intelligent nozzle motions became the norm for automated airblast machines with different styles of motion control systems, resulting in greater predictability of the cleaning or peening outcome.

Have we capitalized on everything our PLCs, motion-control systems and robots can offer? Robert B. Heaton is the Product Support Manager at Empire Abrasive Equipment and specializes in automated airblast equipment. He has worked with several versions of controls in cleaning and peening equipment over the years. "Our industry's use of the PLC, PC and motion controls compares to a high school student's limited use of a simple yet powerful scientific calculator. Controls have tremendous potential to make cleaning and peening processes intuitive. They can play a much greater role in equipment maintenance in ensuring the downstream collation of process information. What's currently being done on a small scale could be expanded for greater functionality of control systems," said Mr. Heaton.

- Advancements in wheel / nozzle technology, blast media, and controls have facilitated newer applications such as medical implants and composites, and have increased the value in existing applications, such as the dual peening of automotive gears.
- The venturi-style nozzle is a notable evolution in the airblast style of media propulsion. The venturi-style nozzle produces a higher velocity and greater abrasive impact with a uniform spread of abrasive. Its straight-orifice counterpart concentrates abrasive in the center of the pattern with little abrasive spread on the pattern's outer edges. Though straight-bore nozzles do have their own special applications, the venturi-style nozzle delivers better results with the same energy consumption.

  Blast nozzle technology seems to have suffered from the same issues that slowed the growth of the overall industry. Though the industry saw the introduction and adoption of multiple discharge nozzles, angled discharge nozzles and lances, and deflector pins for small bore and slot peening, there is still room for growth in this sector. How about cost-effective designs for better access to intricate areas? What about nozzles made from better quality materials with automated wear indicators so that we don't have to rely on incorrect peening results as an indicator of nozzle deterioration?

This is not all. Our industry has seen other areas of growth, arguably of lesser impact, in the following:

- Insulation initiatives to contain source noise, sometimes under 75dbA, using innovative materials and cabinet designs.
- Tagging along with advancement in controls, we have pressure monitoring and control through PID loops, closed-loop media flow control valves, both ferrous and non-ferrous, and media size and shape control.
- The remote monitoring of a machine's health that links the supplier and end user.
- Adoption of newer types of blast media for peening applications, such as conditioned cut wire and ceramic. Improved media would give lower breakdown rates, lower dust generation and a more efficient transfer of impact energy, ultimately improving repeatability and consistency of results.
- Cleaner ventilation and dust collection techniques, including advanced fire-retardant cartridge filter material and filter design.
- At the downstream end of shot peening equipment, X-ray diffraction techniques that allow almost real-time measurement of residual compressive stress.

THE NEXT QUANTUM LEAP

Let's start with blast cleaning. This process is utilized for (a) cleaning contaminants such as rust or scale for the purpose of a downstream coating process, and (b) removing heat treat scale off casting in foundries. We cannot do much with the latter except in terms of maintenance initiatives, but let us look at the former.

What if there was a technique to coat the part downstream from blasting either within the blast machine itself or in a similar set-up? What if a counterpart to the blast wheel could cover the part with paint or any other coating just like a blast wheel cleans the component? This will allow sharing of blast cleaning technology with coating technology—a natural progression of industry groups! A visit to your local paintball facility will demonstrate that this thought is not all that far-fetched.

We are already able to analyze the component being blast cleaned in terms of geometry and surface area and then estimate the exact amount of paint consumption, allowing for waste. What if this technology was applied to shot peening and it allowed us to estimate the time required to achieve 100% and multiples of coverage in the form of an algorithm? Production rate estimates for peening applications will gain better accuracy, particularly for automotive applications.

INNOVATING IN **SHOT PEEN TECHNOLOGY**

Shot Peening Division

Straaltechniek International is one of the few companies that both designs and manufactures shot peening machines.

Built by innovators

Continuous improvements and higher standards are set after each delivery of a Straaltechniek International machine.

Straaltechniek International BV | Shot Peening Division
Oosterhout - The Netherlands
info@straaltechniek.net - www.straaltechniek.net

Shot peening has enjoyed more technological growth than blast cleaning. Advancements in this sector have been duplicated in less critical applications such as etching, de-burring and cleaning. With all this, users continue to rely on a standard strip of spring steel to provide them with assurance on the fatigue life of critical components. There is no doubt that the Almen strip does its job of representing the residual compressive stress on the component being peened. However, it is now getting common for the end user to specify requirements and assurance of residual compressive stress values without the traditional considerations to arc heights and intensity measurement on the Almen strip.

Is this the future of how suppliers will have to prove-out their shot peening equipment and the process? Would this mean our allegiance to the Almen strip will take a backseat to sophisticated X-ray diffraction or some other technique to measure residual compressive stress through non-destructive means?

Saturation curves are the shot peening industry's measure of process reliability and stability. If we were able to directly and reliably measure residual compressive stress on a component, is there a need for plotting these saturation curves? With the real-time *reliable* and *repeatable* measurement of residual compressive stress, saturation curves wouldn't be necessary.

Are there other techniques to impart/transfer energy on to a component that undergoes cyclic loading? How about steam? If vapors have the strength to cause cavitations, can this be harnessed instead to create residual compressive stress? A 3/8" nozzle consumes about 175 CFM of compressed air at 90 PSI. Is there any way to capture the energy remaining in the shot particle after it has bounced around the part being peened or cleaned? Much like a supercharger in our cars?

Even as we review the technologies that will take us to the next levels, we can't ignore the fact that this is a maintenance intensive process. We also cannot underestimate the impact of human interaction. This carries equal importance before and after the sale. "Before" in order to recommend the right machine, and "After" to assist with trouble-free operation. Let us look at some of the possible machine features that could ease maintenance concerns:

a. Predictability of machine component life and visual indicators of stages of deterioration. This feature already exists in blast wheel designs with some wheelblast machine manufacturers. Expanding it to other critical components will help predict component wear.

b. End-users embracing the concept of sharing their machine performance electronically with the equipment/spare part manufacturer in order to maintain a lean inventory of spares at site. This would benefit the end-user as well because the supplier would maintain requisite levels of spares inventory for immediate dispatch.

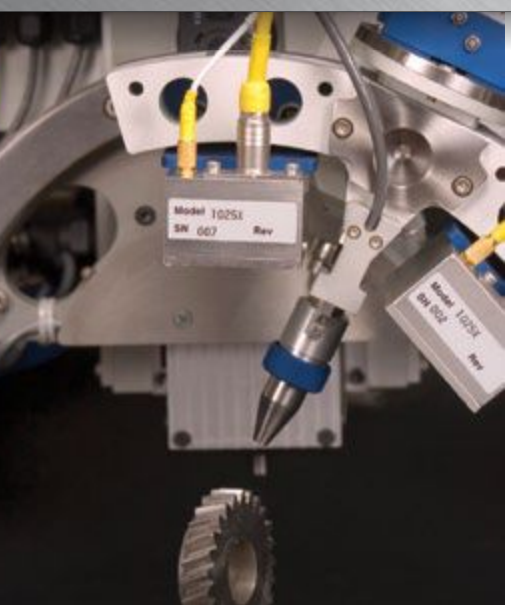
What role does temperature of the component play in peening coverage? There has been some research in this area with springs. Is there a benefit in expanding our research in this area? Perhaps this can reduce processing time if coverage benefits from elevated temperatures.

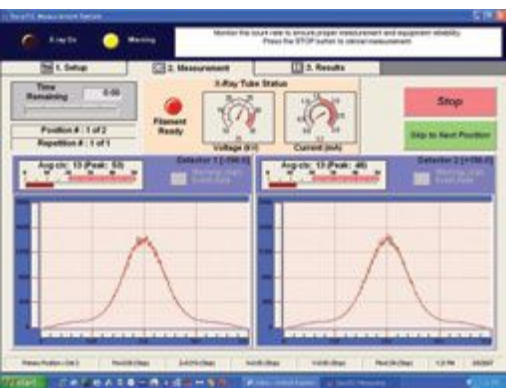
WHERE DO WE GO FROM HERE?

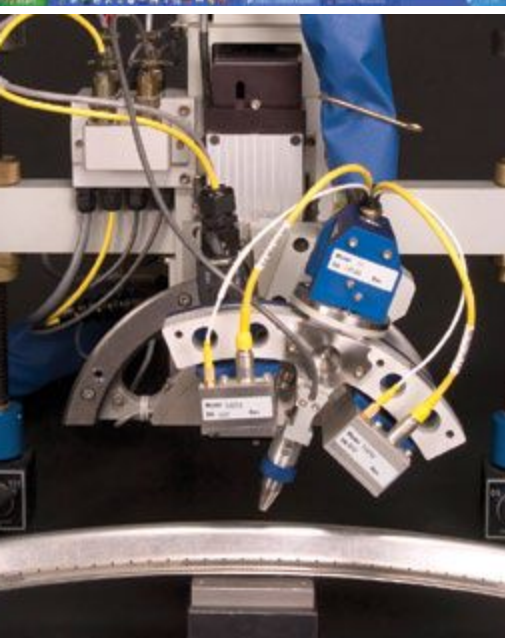
If growth is our goal, status quo is not a choice. Development is no longer the domain of a particular global geography. This industry thrives from lessons learned in the field. This means there has to be a mechanism to transfer the lessons back to the design office. Once again, machine controls could play a larger role and reduce dependence on manpower to close this feedback loop. The industry's future will benefit from a collaborative approach between its equipment, consumable suppliers and end-users. We cannot afford to rest on our past experiences and stay within our comfort zone. If we have to benchmark our industry among related equipment sectors, the attributes of faster, less expensive and better quality scream out loud.

As I see it, all of us have a vision of what features will be in our automobiles in another 10 years—why not visualize where we want our cleaning and peening equipment to be?

Materials Testing Services







When you use TEC's accredited laboratory, you can be sure that you will receive superior analysis and technical support. We meet today's strictest quality standards by maintaining A2LA accreditation and ISO-9001 registration. Scheduled turnaround of analysis results is always rapid, however, we can also adapt to meet critical deadlines when you need immediate results.

Residual Stress

By managing residual stresses during the manufacturing process, you and your customers can reduce failures caused by phenomenon such as fatigue and stress corrosion cracking.

Retained Austenite

We calculate retained austenite using the four-peak method of measuring two austenite and two martensite peaks - recommended by both ASTM and SAE for obtaining accurate results.

In-House or Field Services

Utilizing the portability of our own X-Ray Diffraction System, TEC lab personnel can perform measurements on parts ranging from a fraction of an inch to several hundred feet with guaranteed rapid and precise results.

At TEC, our customers are our partners. Our expert staff is dedicated to helping you meet your own quality control demands. Contact us today for more information.

TEC

ACCREDITED

865.966.5856

www.TECstress.com

ISO REGISTERED 9001

Materials Testing Division • 10737 Lexington Drive • Knoxville, TN 37932 USA

by John Cammett - Consultant | Je Derda - Electronics Inc.

So You Think Almen Strip Coverage Is Important?

YES, IT IS, but only in a limited sense. Almen strip coverage is important in that it must be uniform because that is an implicit and necessary condition to ensure that intensity determination via a saturation curve will be correct. Otherwise, Almen strip coverage is unimportant! One of the authors, John Cammett, has published articles on the general subject of coverage in the two previous issues of this publication. The first article, *The Time Paradox in Peening*, dealt with the separate issues of Almen strip exposure time for intensity determination and part exposure time in the peening process. The second article, *Are You Peening Too Much?*, dealt with the desirability of peening to lower coverage values than is conventionally practiced, that is, 80% coverage instead of 100%. While having no intention of writing a third article on the subject, the authors decided to address specifically the issue of Almen strip coverage and its relationship to part peening coverage.

The authors assert that there is no relationship between Almen saturation time and part coverage in peening despite some peening specifications and instructions which incorrectly imply otherwise. In a sense, this article deals with the same issues as the first, but here the emphasis is different. The fundamental flaw in using Almen saturation time to represent time to full-part coverage in a peening process is that the part hardness is likely to be different from the Almen strip hardness. Thus, the part will respond to peening differently from the Almen strip in terms of coverage rate and the part coverage time will not relate to Almen saturation time even if area and geometry are compensated. Additionally, you will probably be surprised to learn that the Almen strip is generally not fully covered at the saturation time. Please read on for further supporting arguments and evidence.

PEENING LIKENED TO HARDNESS TESTING

The effect of a single piece of shot on a metal surface is much like the effect of an indenter used for testing hardness. In order to determine the hardness of a metal, a shaped indenter is driven into the surface of a work piece using a controlled force. The depth to which the indenter penetrates the surface determines the hardness. (The deeper the dent, the softer the metal.) When the indenter is removed, the impression from the indenter remains, along with the associated compressive stresses.

In the case of peening, the indenter is a media particle, hopefully spherical or nearly so, which impacts a part surface and leaves an impression of itself (dent) after rebounding. Schematically, a diametrical cross-section of a peening dent and surrounding material is shown in Figure 1. Analogously to a hardness impression, for given energy of impact and appropriate media particle properties, the dimensions of a peening dent are inversely related to the part material hardness, elastic modulus and/or plasticity-related properties. The size of the plastic zone surrounding the dent is also related to the impact energy and material properties, but it is beyond the scope of this article to attempt to relate details of this relationship. Let it suffice for current purposes to say, however, that the sizes of shot peening dents (and associated plastic zones) are inversely related to part hardness for given impact energy (intensity), media type and size.

PEENING DENT SIZE AND COVERAGE

It follows directly from the above that the sizes of shot peening dents will be different in materials of different hardness. For a given intensity, materials of lower hardness will exhibit larger dents than in those of greater hardness and vice versa. For a given rate of denting (the media impact rate), coverage which is a measure of the accumulation of dents will occur sooner when dents are larger than when they are smaller. Per SAE J442, Almen strips are required to have hardness in the range of HRC 44-50 (45-48 HRC for aerospace strips per AMS 2432). Thus, if your part hardness is different, either greater or less, from the Almen strip hardness, you could not expect coverage in the part to occur in a time similar to that in an Almen strip. Even if the part hardness is similar to the Almen strip hardness, coverage times may not be

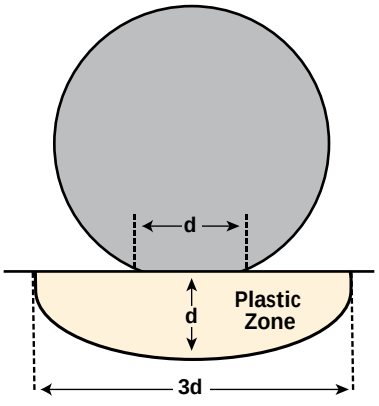


Figure 1. Schematic Illustration of Diametrical Section through a Peening Dent

equivalent if plasticity characteristics such as work hardening response and recovery are different. (Authors' note: The latter statement, though believed true, has not been verified and merits further study.)

ALMEN STRIP COVERAGE AND SATURATION TIME

A comprehensive experimental study of the time relation between Almen strip coverage and saturation time was performed by one of the authors, Jeff Derda, and reported in a poster session at ISCP11 in 2011. Test results are shown in Figure 2. The experimental details were as follows:

- Three media sizes – S330, S230, S110
- Two air pressures – 25 and 50 psi (1.72 and 3.44 bar)
- Other peening parameters: 0.36-inch (9.14 mm) nozzle diameter, 10 pound-per-minute shot flow rate (4.53 kg), 6-inch nozzle height above strips (152.4 mm), 90˚ incidence

Six sets of Almen strips (all strips from same production lot) for each given media size, air pressure and other fixed parameters were affixed in standard holders arranged on a turntable that rotated through the media stream in an equivalent manner. After peening each set of strips for one to as many as 27 revolutions, arc height versus revolutions results were analyzed via the computerized Kirk Curve Solver to determine the intensity and saturation time for each.

Strips were visually examined by the procedure in SAE J2277 to establish that full coverage (98%) had been attained in each set. Further coverage measurements were made with the Toyo Seiko Coverage Checker.

It was concluded that saturation time in a given set of strips always occurred before full coverage. The ratio of full coverage time to saturation time varied from 1.5 to 3.1 for the six sets of strips and thereby proving that there is no correlation between Almen saturation time and strip coverage. (See Figure 2.)

SUMMARY

By fundamental logic and argument regarding hardness differences, the authors established that there is no general relationship between Almen saturation time and peening coverage time for parts. Further, testing has demonstrated that even for Almen strips, there is no systematic relationship between strip saturation time and coverage.

Do you still believe that Almen strip coverage is important and that part coverage in peening should be based upon saturation time?

Test Settings — S-390 — 25 PSI — 10.0 lb/min

Sample	# of Revolutions	Arc Height (Inches x .001)	% Coverage
1	1	3.1	36
2	**3**	**7.1**	**40**
3	5	9.5	79
4	**7**	**10.9**	**82**
5	9	11.6	82
6	**11**	**12.6**	**85**
7	13	13.3	86
8	**15**	**13.8**	**93**
9	17	13.9	95
10	19	14.0	97
11	21	14.1	99

Saturation Time	12.3 Revolutions
Coverage/Saturation	1.71

Test Settings — S-230 — 25 PSI — 10.0 lb/min

Sample	# of Revolutions	Arc Height (Inches x .001)	% Coverage
1	1	4.4	28
2	3	7.4	46
3	5	8.6	86
4	7	9.1	65
5	9	9.6	73
6	11	10.1	83
7	13	10.3	95
8	15	10.5	87
9	17	10.5	85
10	19	10.6	92
11	21	10.9	93
12	23	10.9	96
13	25	10.9	94
14	27	11.1	98

Saturation Time	8.6 Revolutions
Coverage/ Saturation	3.14

XX = Measurement error caused by slightly darker strip surface.

Test Settings — S-110 — 25 PSI — 10.0 lb/min

Sample	# of Revolutions	Arc Height (Inches x .001)	% Coverage
1	1	3.8	67
2	3	5.6	80
3	5	5.9	99
4	7	6.2	98
5	9	6.4	98
6	11	6.6	99

Saturation Time	4.1 Revolutions
Coverage/ Saturation	1.22

Test Settings — S-390 — 50 PSI — 10.0 lb/min

Sample	# of Revolutions	Arc Height (Inches x .001)	% Coverage
1	1	8.1	49
2	**3**	**14.4**	**52**
3	5	17.2	61
4	**7**	**18.8**	**73**
5	9	20.3	81
6	**11**	**21.0**	**78**
7	13	21.9	84
8	**15**	**22.5**	**97**
9	17	23.2	89
10	**19**	**23.4**	**95**
11	21	23.8	94
12	23	24.1	99

Saturation Time	12.2 Revolutions
Coverage/ Saturation	1.89

Test Settings — S-230 — 50 PSI — 10.0 lb/min

Sample	# of Revolutions	Arc Height (Inches x .001)	% Coverage
1	1	8.6	48
2	3	12.4	67
3	5	14.0	84
4	7	14.8	89
5	9	15.3	95
6	11	15.7	96
7	13	15.9	100
8	15	16.0	98
9	17	16.2	99
10	19	16.2	100

Saturation Time	5.8 Revolutions
Coverage/Saturation	2.24

Test Settings — S-110 — 50 PSI — 10.0 lb/min

Sample	# of Revolutions	Arc Height (Inches x .001)	% Coverage
1	1	7.2	60
2	3	8.4	83
3	5	8.9	93
4	7	9.4	95
5	9	9.5	97
6	11	9.6	97
7	13	9.7	98
8	15	10	99
9	17	9.9	99

Saturation Time	1.4 Revolutions
Coverage/ Saturation	9.29

Figure 2. Test results from "Time Relationship Between Saturation and Coverage" study

High precision peening equipment for aerospace

Peening solutions for landing gear

Whether you are peening large areas with centrifugal wheels or targeting specific areas with CNC automated airblast nozzles, Wheelabrator equipment will allow you to comply with AMS 2430/2432, Boeing 5730 specifications and NADCAP audit criteria.

Contact us to find out how.
US: 800-544-4144 • Canada: 800-845-8508 • info@wheelabratorgroup.com

wheelabrator
shaping industry

www.wheelabratorgroup.com

Norican Group is the parent company of DISA and Wheelabrator.

ACADEMIC STUDY
by Dr. David Kirk | Coventry University

Quantification of Shot Peening Coverage

INTRODUCTION

Shot peening is essentially a surface metalworking process. A stream of high-energy shot particles does work on the surface of components. The work done manifests itself in the form of dents. Coverage with dents increases with peening time. The progress of coverage is illustrated in fig.1. The rate of increase in coverage slows down with increase in the amount of peening – following the "Law of Diminishing Returns." An important practical requirement is that the applied shot stream must achieve a required degree of coverage in an economical time. As coverage increases a surface layer of work-hardened, compressively-stressed component material is generated. It is this "magic skin" that promotes improvement in service performance.

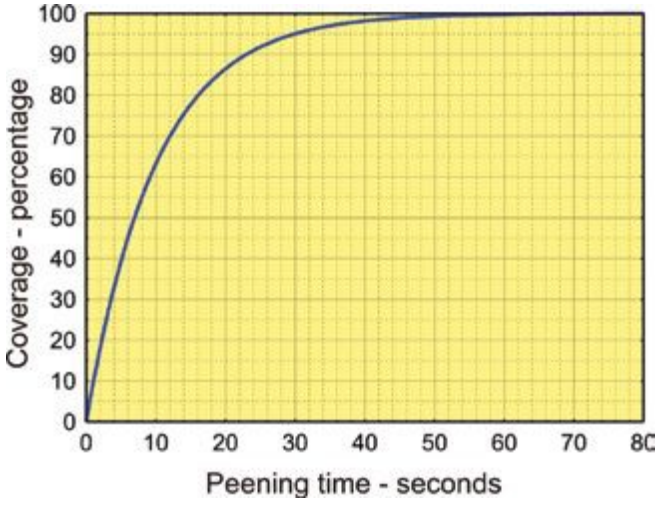


Fig.1. Typical Coverage/peening time curve.

The shot stream itself must have a specified intensity level, e.g., N254 (Almen N strip deflecting by 0.254 mm at a particular time of peening, T). This is an identifying parameter. There is, however, currently no specified parameter that quantifies a shot stream's ability to achieve required coverage levels.

This article considers, in quantitative terms:

(1) Particle Work Capability,

(2) Dent formation,

(3) Coverage evolution and

(4) Coverage versus Peening Intensity.

A suggested identifying parameter for a shot stream's ability to achieve required coverage levels is described in some detail.

1 PARTICLE WORK CAPABILITY

Each effective shot particle has some capability for doing work on a component's surface. This capability depends upon the kinetic energy possessed by the particle. It is not commonly recognized that work units and kinetic energy units are identical, i.e.:

The units for work can be expressed as either N*m or $kg^{*}m^{2*}s^{-2}$.

Work is force (in Newtons) multiplied by distance (in meters) so that:

$$\textbf{Work units} = N^{*}m \qquad (1)$$

Kinetic energy, $\frac{1}{2}mv^2$, has units of **kg** (for the mass, **m**) and of $m^{*}s^{-1}$ (for the velocity, **v**). Hence by inserting these units we have that:

$$\textbf{Kinetic energy units} = kg^{*}m^{2*}s^{-2} \qquad (2)$$

Force, which has the unit of Newtons, **N**, is equal to mass (in **kg**) multiplied by acceleration – which has units of $m^{*}s^{-2}$. Hence we get that:

$$\textbf{Force, N} = kg^{*}m^{*}s^{-2} \qquad (3)$$

If we multiply both sides of equation (3) by **m** we get that for work units:

$$N^{*}m = kg^{*}m^{2*}s^{-2} \qquad (4)$$

(2) and (4) are identical. It therefore follows that the work capacity for an individual shot particle can be expressed as either N*m or $kg*m^{2*}s^{-2}$.

The mass of a particle is its volume multiplied by its density, ρ. The volume of a spherical particle is $\pi*D^3/6$ (D being diameter) so that its mass is $\pi*D^{3*}\rho/6$. Substituting this expression for mass into $\frac{1}{2}mv^2$ gives that a spherical particle's kinetic energy is $\pi*D^{3*}\rho*v^2/12$. Now a particle's kinetic energy is the same as its capability for doing work on a component, W_P. Hence $W_P = \pi*D^{3*}\rho*v^2/12$. Dividing by 10^6 (to give D in mm and W_P in Nmm) gives:

$$W_P = \pi^{*}D^{3*}\rho^{*}v^2/(12^{*}10^6) \qquad (5)$$

Where W_P is particle work potential in Nmm, **D** is particle

COMCO

PRECISION SHOT PEENING EQUIPMENT

Creating a New Standard of Precision for Today's Shot Peening Applications

Three Sizes of Media Stored and Ready for Use
Ferrous & Non-Ferrous Media Delivery
Peens Multiple Parts at the Same Time
Offers Advanced Multi-Media Handling
Peens .125" Internal Diameters
Reduces or Eliminates Masking

To find out more, visit our website at www.comcoinc.com
2151 North Lincoln Street I Burbank, CA 91504 I USA
(800) 796-6626 or sales@comcoinc.com

Engineered Abrasives™

Manufacturers of the Finest Blast Finishing and Shot Peening Systems

(708) 389-9700 or (773) 468-0440

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

ISO/TS16949
ISO 14001
FORD Q1
Certified
Job Services

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

48" Single Cell Shot Peen System

6 Suction Nozzles 1 Pressure Nozzle

All Nozzles MagnaValve® Controlled

Sweco, Oscillating Nozzles and Rotary Lance

60" Index Unit Ring and Pinion Gears for High Volume

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

CONTROL by MagnaValve®

All Tooling and Fixtures A2 Tool Steel Hardened

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

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

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

The largest 5-Axis CNC 96" Shot Peening Index Table made. Two-media capacity with MagnaValves® for large rings and pinions up to 33" O.D. Designed for higher volumes. (GE 31-i Series Controller)

Large 84" Index Unit for high volume

12 Pressure Nozzles with MagnaValves®

Automatic load/unload 1,000 gears per hour

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

diameter in mm, **v** is particle velocity in ms^{-1} and **ρ** is particle density in kgm^{-3}.

Equation (5) can be used to estimate the work capability of individual shot particles e.g. as in fig.2. A 'mental picture' of the magnitude of the capabilities can be gained from the following example. Imagine an average-sized apple – it has a mass of approximately I Newton (remember that Sir Isaac Newton supposedly devised the Law of Gravity after seeing an apple fall in his orchard). Lifting this average-size apple by 100 mm (4 inches) requires 100 Nmm of work to be done on it.

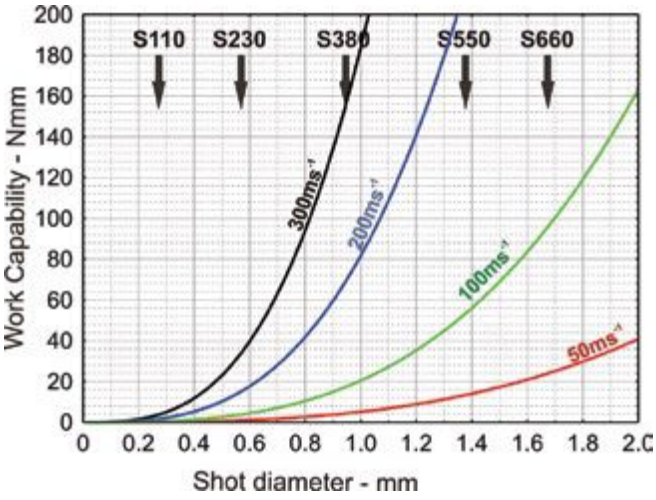


Fig.2. Steel shot work capability variation with diameter and velocity.

2 DENT FORMATION

Having quantified the work capability of an individual shot particle we can now estimate its ability to form a dent. When a high-velocity particle strikes a component's surface it loses a large part of its work capability. The greatest loss is caused by heat generation. Less than a tenth of the work capacity is used up in creating a dent. The previous section showed how the particle's work capacity can be calculated. This section shows how the amount of work needed to create a given dent can be estimated.

On initial contact with the surface the force being exerted on the surface by the impacting particle is zero. That is because force is stress multiplied by the area of contact – which initially is zero. The stress being applied is the compressive yield strength of the component. As the particle forces its way deeper into the surface the contact area grows. As a consequence the force grows. When the particle has its forward movement stopped the contact area is at its maximum so that the force being exerted is at its maximum. Fig.3 illustrates this progression from initial contact at (a) to maximum contact area at (b) when the dent depth is H.

The area, A, of contact between a spherical shot particle and a flat surface is given by:

$$\mathbf{A = \pi^{*}D^{*}h} \qquad (6)$$

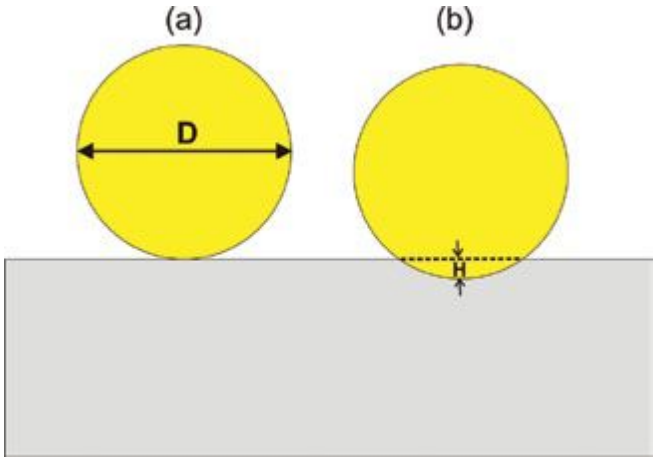


Fig.3. Progressive indentation by a shot particle to create a dent.

Where **D** is the particle's diameter and **h** is the depth of the dent.

h in equation (6) has a value of zero on initial contact and rises to a maximum of **H** (see fig.3).

Exerted force is yield stress, **Y**, multiplied by area over which that stress is applied, **A**. Hence the force, **F**, being exerted by the particle during impact is given by:

$$\mathbf{F = \pi^{*}D^{*}h^{*}Y} \qquad (7)$$

The amount of work, W_D, which has to be done to create a typical dent, is the area of the blue right-angled triangle in fig.4. Area of a right-angled triangle is half the product of the base length multiplied by its perpendicular height. For the example shown, the area would be 126*0.08/2 N*mm or 5 N*mm.

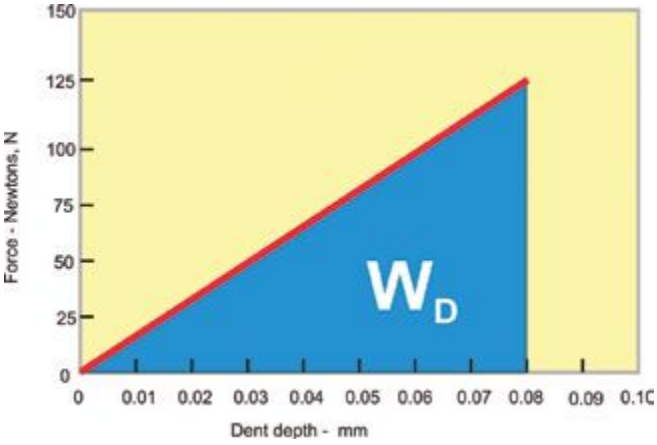


Fig.4. Example of force variation with dent depth - indicating work done.

The following example shows the calculations needed to determine the values shown in fig.4.

Example of work done in creating a dent

Assume that a spherical particle has a diameter of 1 mm

IPS....

Innovative Peening Systems

Fanuc CNC Controlled

Rotary Lance

S Series
Five Axis CNC
Computer Controlled
Shot Peening Machine

Part Capacity
24” dia x 36” high

L Series
Six Axis CNC
Computer Controlled
Shot Peening Machine

Part Capacity
48” dia x 48” high

Innovative Peening Systems
2825 Simpson Circle
Norcross, GA 30071
770-246-9883

CNC is no longer exclusive to the Fortune 500

Our affordable CNC machines allows every shot peener to eliminate manual nozzle setups. CNC offers exceptional part processing speeds, accuracy of peening and consistent quality of parts.

and produces a dent 0.08 mm deep in component material that has a constant yield strength of 500 Nmm^{-2} (500 MPa). Substituting these values into equation (7) gives that the maximum force, $\mathbf{F_{max}}$, is given by:

$\mathbf{F_{max} = \pi * 1mm * 0.08mm * 500\ Nmm^{-2}}$ so that
$\mathbf{F_{max} = \pi * 1 * 0.08 * 500\ N}$ giving
$\mathbf{F_{max} = 126\ N}$

The work done in creating the dent, $\mathbf{W_D}$, is the area of a triangle whose height is $\mathbf{F_{max}}$ and whose base is the depth of the dent. Hence we have that:

$\mathbf{W_D = 126N * 0.08mm/2}$ giving that
$\mathbf{W_D = 5\ N*mm.}$

As stated previously, less than a tenth of a particle's work capability can be translated into the work of dent creation. The particle must therefore have a work capacity at least ten times the magnitude of the dent creation work requirement. We can now compare the dent creation work requirement with the work capacity of a flying steel shot particle – using fig.2. If we assume that the particle is S380 then it would have to be travelling at about 180 $m*s^{-1}$ in order to have 50 N*mm of work capacity – the amount required to produce a dent about 0.08 mm deep.

There is a quantitative relationship between the work capability of a single shot particle and the diameter of the indent produced on striking a component. That relationship was originally presented by the author in a previous TSP article – Spring, 2004. In terms of work capability that relationship can be expressed as:

$$\mathbf{d^4 = D^4 * P * W * 1000 / B} \qquad (8)$$

Where **d** is the indent diameter in mm, **P** is the proportion of the work potential used in dent creation, **W** is the work potential in N*m, **D** is the particle diameter in mm and **B** is the Brinell hardness of the component in MPa. The usually-quoted kg/mm^2 value for **B** has to be multiplied by 9.8 to give its MPa equivalent.

Equation (8) is useful in several ways: for predicting the separate effects of particle diameter, particle work capability and component hardness on indent diameter.

3 COVERAGE EVOLUTION

Peening involves vast numbers of particles impacting the component's surface. These particles progressively cover the surface with dents. Users specify the extent of the coverage that they require for particular components. For every specified peening operation the coverage achieved is determined by two factors (a) the coverage factor, K, of the shot stream on impact and (b) the time of peening.

Coverage Factor, K

K is A multiplied by N where A is the average projected area of each dent and N is the rate of dent creation per unit area of the component being peened. For example: assume that the average area of each dent, A, is 0.01 mm^2 and that the rate of dent creation, N, is 10 dents per mm^2 per second. The value of K (A multiplied by N) is then 0.1 per second (the mm^2 cancelling each other).

An equation relating dent creation rate to coverage was presented at ICSP5 by Kirk and Abyaneh. Expressed in terms of the coverage factor this equation is that:

$$\mathbf{C = 100(1 - exp(-K*t))} \qquad (9)$$

Where **C** is the coverage percentage, **K** is the coverage factor and **t** is the time when dents are being created (actual peening time).

Substituting 0.1 for **K** in equation (1) gives that $\mathbf{C = 100(1 - exp(-0.1*t))}$. Fig.5 represents the form of this equation. One useful feature of this exponential coverage curve relates to the peening time, T, that gives 90% coverage. If we double that time to 2T we get 99% coverage, 3T gives 99.9% coverage, 4T gives 99.99% coverage and so on. When K = $0.1s^{-1}$ 90% coverage occurs at 23 seconds and 99% at 46 seconds and so on. So-called "full coverage" is defined as 98% or greater - based on measurements above 98% not being of acceptable accuracy and repeatability. When K = $0.1s^{-1}$ 98% coverage occurs at a time of 39.1 seconds.

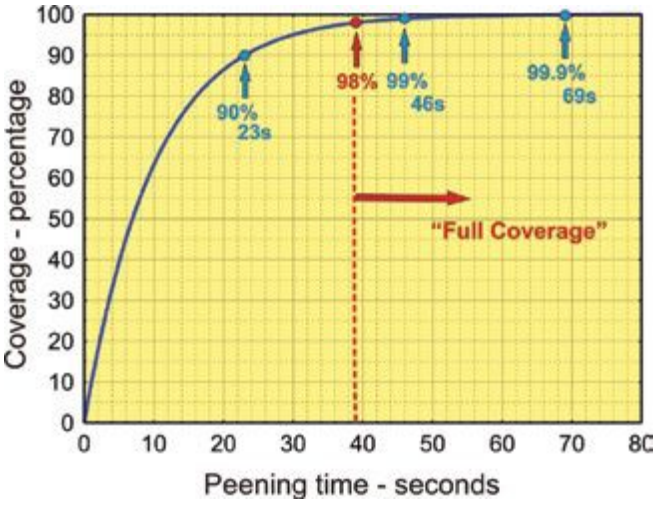


Fig.5 Coverage curve when Coverage Factor equals $0.1s^{-1}$.

When coverage reaches a very high value any further peening is generally wasteful. K can also be expressed as "per pass" rather than "per second." In this case the N is determined per pass rather than per second.

Reasonable maxima can be assumed for either the time of peening or the number of passes that will be employed on a given component. Assuming that these are 100 seconds and 10 passes respectively the effect of different coverage factors can be expressed graphically – as shown in figs. 6 and 7.

2015
Shot Peening Training

Improve your skills,
reach your professional goals

Learn from expert instructors
on relevant topics

FAA-accepted courses,
Nadcap Partner in Education

Tokyo, Japan ..... *February 2015*
Seminar in 日本語

San Miguel De Allende, Mexico ..... *March 2015*
Seminar in Español

Montreal, Canada ..... *May 2015*
Seminar

Singapore ..... *June 2015*
Seminar

Shenzhen, China ..... *June 2015*
Seminar and Workshop in 普通话 (Mandarin)

Visit shotpeeningtraining.com for more information

Receive recognition for achieving a higher level of shot peening education. Seminar, workshop and on-site training attendees are eligble to take our FAA-accepted shot peening and flapper peening achievement exams.

On-site training programs are also available

Train on your equipment • Can be customized • Includes facility and equipment review
Training can be held any time of year • Ideal for five or more employees

EI Shot Peening Training

www.shotpeeningtraining.com
(574) 256-5001 or 1-800-832-5653

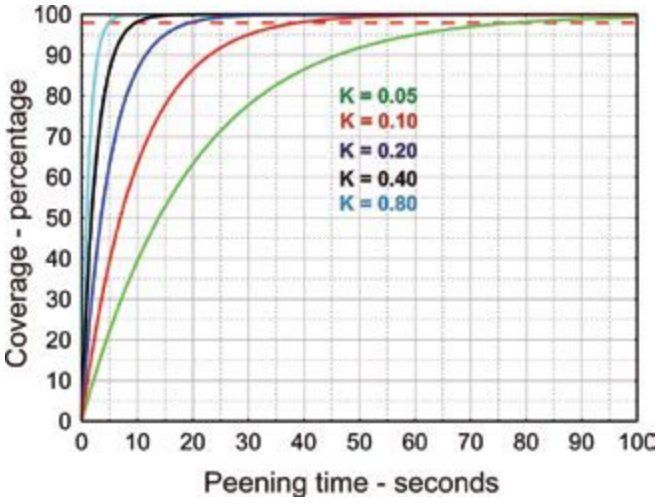


Fig.6 Effect of Coverage Factor on coverage/ peening time curve.

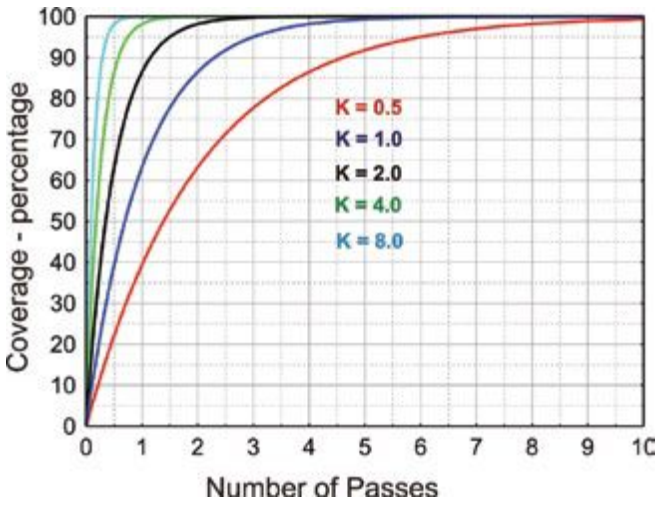


Fig.7 Effect of Coverage Factor on coverage/ number of passes curve.

Commercial values of K depend on the type of peening operation and its parameters. K values can be either measured or predicted for particular operations. The following is an example of the steps involved for air-blast peening.

Example of Coverage Factor Estimation for Air-blast Peening

For this example it is assumed that a conical shot stream is striking a flat component producing a circular impact zone whose diameter is **D** and whose area is **Z**. It is further assumed that the shot stream is being traversed linearly at a rate **TR**, that the feed rate of shot is **FR** and that the shot particles produce indents whose average area is **A**. Fig. 8 illustrates the variables.

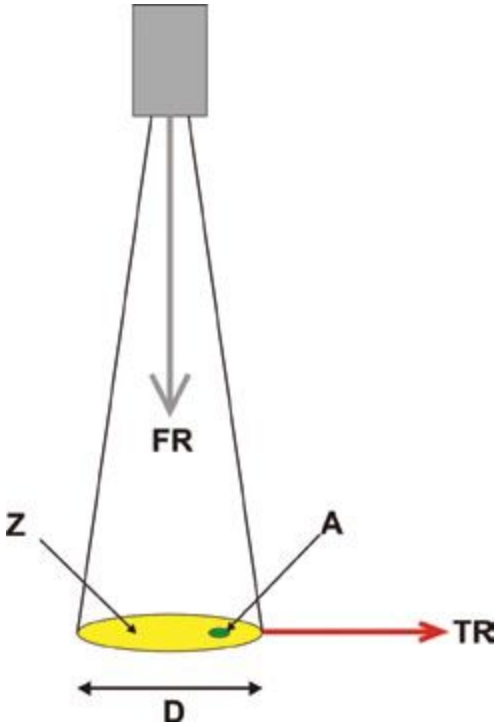


Fig.8. Coverage Factor variables.

The coverage factor for stationary peening (i.e. zero traverse rate) can be estimated using the following expression:

$$\mathbf{K = FR^{*}A/(m^{*}Z)} \qquad (10)$$

Where **m** is the average particle mass.

As an example, assume that: a feed rate of 50 $g^{*}s^{-1}$ is used to feed S170 shot; the impact area, **Z**, is 1300 mm^2 (**D** being 50 mm) and impact dents have an area, **A**, of 0.01 mm^2. The average particle mass, **m**, for S170 shot is $0.33^{*}10^{-3}$g. Substituting these values into equation (10) gives that:

$$\mathbf{K(s^{-1}) = 50^{*}0.01/(0.33^{*}10^{-3}{}^{*}1300)} \text{ so then:}$$

$$\mathbf{K = 1.2\ s^{-1}}$$

The average coverage factor, K_{AV}, for a stream that is moving relative to the component can be estimated using a modified form of equation (10):

$$\mathbf{K_{AV} = FR^{*}A^{*}D/(m^{*}Z^{*}(TR + D))} \qquad (11)$$

Where **TR** is the transfer rate per second.

Using the same values as in the previous example, together with a transfer rate per second of 50 mm, we have that:

$$\mathbf{K(s^{-1}) = 50^{*}0.01/(0.33^{*}10^{-3}{}^{*}1300^{*}(50 + 50))} \text{ so then:}$$

$$\mathbf{K = 0.6\ s^{-1}}$$

Introducing our *Double-Sided* Numbered Almen Strips

with Coverage Check Finish*

The Electronics Inc. Almen strip lot number is now printed at the top of both sides of our Numbered Almen Strips with Coverage Check Finish.* This insures that you always have a legible lot number and plenty of room to add your own notes.

Printing our lot number on both sides of the strips is just one more way our Almen strips contribute to a validated shot peening process.

*** U.S. Patent No. 6,568,239 for Coverage Check Finish**

Electronics Inc. – The Almen Strip Experts Since 1987

We are responsible for every aspect of the manufacturing process to ensure that EI Almen strips qualify to industry specs from standard MIL to aerospace specifications.

Our grading system (3™, 2™, 1™, 1S℠) makes it easy to choose the best strips for your shot peening process including automotive, aerospace and medical applications.

Electronics Inc. maintains a large inventory of Almen strips to insure fast delivery around the world.

1-800-832-5653 or 1-574-256-5001 | www.electronics-inc.com

Ask for the results of our Almen Strip Consistency Testing Program. We can prove that our strips are nearly identical in lot-to-lot arc height results from month to month, year to year.

Electronics Inc.
Shot Peening Control

This result indicates, as would be expected, that coverage would then occur at half the rate of an equivalent stationary shot stream.

Equations (10) and (11) quantify well-established knowledge of shot peening parameters. Increasing either the feed rate or the average indent area increases the rate of coverage. Increasing the average particle mass, impact area and traverse rate all reduce the rate of coverage.

4 COVERAGE/PEENING INTENSITY RELATIONSHIP

Coverage is defined as the percentage of a surface that has been covered with impact dents. Peening intensity is defined by a point, P, on a 'saturation curve', see fig.9. This point has, of necessity, two coordinates – H and T. H is the 'h-coordinate' value of deflection at a particular 't-coordinate' value of peening time, T. The magnitude of H therefore depends upon the location of T. As an old song says "You can't have one without the other".

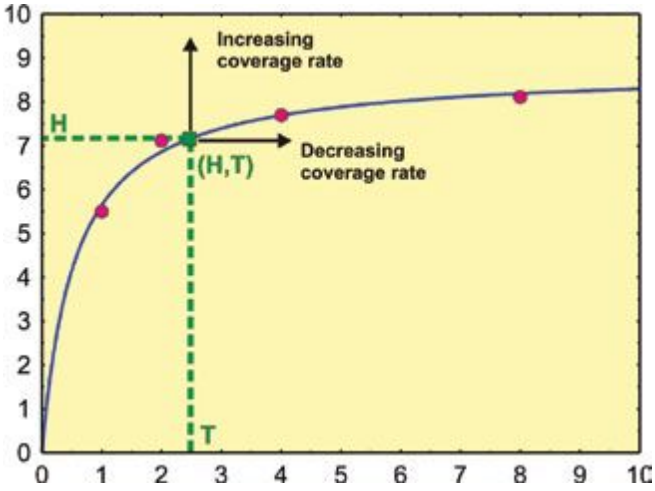


Fig.9 Typical peening intensity curve.

The coverage factor, K, determines the rate at which coverage develops. K is the average area of each dent, A, multiplied by the rate of creation of those dents per unit area of component, N. Now the average area of each dent is directly proportional to the magnitude of H, see fig.9. The value of the H parameter reflects the size of dents – and hence the value of A. Conversely, the time parameter T reflects the rate of creation of dents. It follows that a combination of a low value of H and a large value for T means that coverage (of Almen strips) will progress slowly. Coverage rates achieved for production components will not normally proceed at the same rate as they do for Almen strips. The main reason for this is a difference in the average size of impact dents, A. Components softer than Almen strips will cover faster whereas components harder than Almen strips will cover more slowly. It is, however, possible to allow for the hardness difference – either by prediction or by test measurement.

Some studies have been published for which both coverage and arc height were measured for sets of unpolished Almen strips. Fig.10 gives the first set values from a published study that involved six sets of peened Almen strips. The peening was carried out using a highly-instrumented, highly-controlled, test facility. Simple two-exponent exponential curves have been fitted (by the author) to the first set data. The saturation curve of arc height measurements is a good fit. That indicates that increasing numbers of revolutions increased the amount of work done on the strips in a predictable manner. The curve of coverage measurements is, by way of contrast, not a good fit. Quite surprising is the very small increase in measured coverage between one and three revolutions. The arc height increases substantially, as would be expected, from 0.0081" to 0.0144". Corresponding coverage values only increased from 49 to 52%. The coverage increases (from one to three revolutions) for the other five sets of data were: 48 to 84%, 60 to 83%, 36 to 40% and 67 to 80%. At the 'saturation time' T the measured coverage value was about 75%. Doubling the amount of peening, to 2T, increased the measured coverage value to about a nominal 'complete coverage' level.

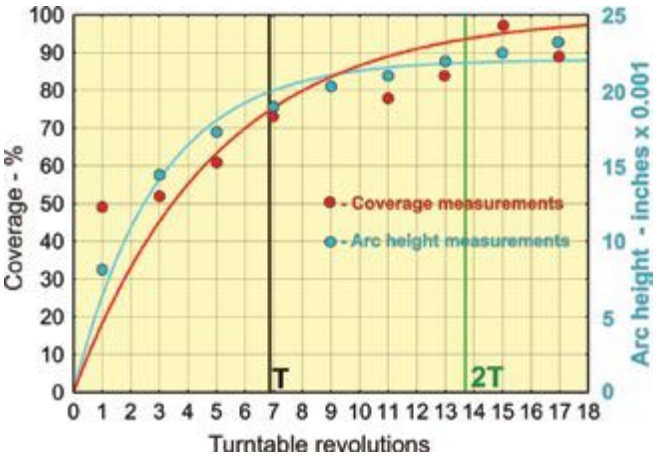


Fig.10. Coverage and arc height measurements on same set of Almen strips.

DISCUSSION

Quantification of coverage is, of course, very important for shot peeners. This article has attempted to show how a Coverage Factor, K, can be used as the basis for controlling applied coverage. This factor can be either predicted or measured.

The progress of coverage with increasing amounts of peening is expected to follow the exponential type of curve shown as fig.1. Experimental verification depends, however, on the accuracy of coverage measurements. The measurements reproduced in fig.10 run contrary to general experience of coverage measurement. The experimental technique used for those measurements should be compared with alternative techniques.

24 Vdc MagnaValves for air-blast machines

24 Vdc MagnaValves for wheel-blast machines

MagnaValve®

Media valves for air-blast and wheel-blast machines

Reduces labor, media and energy costs while adding control and reliability to shot peening and blast cleaning processes

NEW! Non-ferrous media MagnaValve for air-blast machines

You can depend on it

The unique design of the MagnaValve makes it one of the most reliable and hard-working media valves on the market today. Other benefits include:

- Flows most ferrous media and introducing a new model for non-ferrous media
- MagnaValves have companion controllers for accurate and dependable media □ow control
- Compliance to specifications is readily attainable
- Available in 24 Vdc and 120 Vac
- Trusted by OEMs and end-users worldwide

1-800-832-5653 or 1-574-256-5001
www.electronics-inc.com

Electronics Inc.
Shot Peening Control

SAE Specification J2277 "Shot Peening Coverage Determination" provides interesting guidance. Equation (1) of that specification gives a quantitative relationship between coverage and shot stream exposure. This equation predicts an identical curve shape to that of equation (9) in this article. Fig.2 of J2277 gives photographs of coverage induced by applying 1, 2 3, 4 and 6 cycles of peening together with corresponding measured coverage values. These five measured values have been plotted in fig.11. The J2277 equation projects the one-cycle measurement in order to predict coverages with increased numbers of peening cycles. A 'best-fitting' curve of the same shape has been included which confirms that the data set conforms to a predicted simple exponential shape.

It is stressed that the only direct application for Almen strips is to enable the peening intensity of a shot stream to be determined. That does not prevent them from being used for other, 'academic', purposes. Their great advantages for coverage analyses are (a) that they constitute readily-available examples of progressive coverage and (b) that they are of a convenient size and shape for coverage measurements. Actual peened components with different levels of applied coverage are rarely both available and of a convenient size and shape.

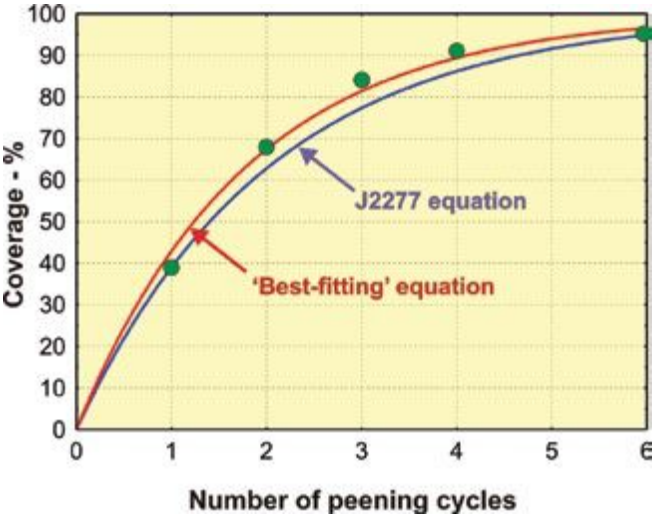


Fig.11. J2277 Coverage measurements

by Erwan Henry | Industry Analyst, Business Developer and Guest Lecturer

Why New is Better

THE GLOBAL ECONOMY is a dangerous place, but it also offers great opportunity.

Competitive pressures keep rising and entire industrial sectors have relocated to markets with lower costs. The surface preparation business has been global for two decades, shrinking in North America, Europe and Japan, but growing nicely elsewhere is the world, especially in the Asia-Pacific zone. The US automotive industry sources most of its castings from Mexico, Brazil, and India. Thailand is producing more cars than Canada or France. Singapore is a global maintenance hub for aircraft and engine maintenance and repair.

Costs Must Shrink. Period!

There is no safe haven for any industrial operation, including shot blasting and shot peening. Remaining cost effective is mandatory to merely stay in business while beating the competition in price is a sure path for growth and profits. Shot blasting and shot peening costs are therefore in the spotlight and deserve the full attention of upper management.

In the summer issue of *The Shot Peener*, we scrutinized the impact of abrasives on shot blasting costs. The conclusion was that the biggest impact of abrasive media was on consumption and energy and it had no significant influence on other items such as labour, wear parts, maintenance, waste disposal, and machine depreciation. Make no mistake, it is obvious that media made with similar production processes and chemistry that exceeds SAE specifications with a narrow standard deviation on hardness in state-of-the-art facilities by well-established manufacturers performs better and triggers a lower operating cost than media that barely meets SAE specs and made in a plant with processing equipment of dubious capability. But when the abrasives are from the "same quality league," it is unrealistic to expect a substantial variation in performance and industrial costs. The difference between two media of the same quality league is slim.

I do not rule out that future stunning innovations in mass-produced metallic abrasives will break the brick wall of performance that we've faced in the last several decades. These new medias will take the entire surface preparation to a new frontier. In the meantime, handsome cost reductions can be achieved with the new generation of blasting machines.

The Numbers Tell the Story

Metallic abrasives consumption is mainly related to the Apparent Steel Usage (ASU) (2/3) and to the automotive industry (1/3). Steel is transformed into plates, structures, pipes, castings, etc., requiring a shot-blasting process at some point. (See chart on page 40.)

When we look at this big global picture between 2004 and 2012, we observe the global ASU surged by 47% and the number of vehicles produced grew by 30%, while the metallic abrasives consumption increased by 16%. On a yearly basis, the average discrepancy between the growth of the metallic abrasives and the shot-blasting outlets is 2.6%.

If we make the same comparison, excluding China which is possibly distorting the comparativeness of these statistics (in other words, the ability to compare apples to apples), we observe ASU developed by 11% and the number of vehicles produced grew by 10%, while the metallic abrasives consumption increased by 6%. On a yearly basis, this average discrepancy between the growth of the metallic abrasives and the shot-blasting outlets is 0.5%.

A short comment on China: The quality improvement of the Chinese metallic abrasives partly offsets the growth consumption trend and this blurs the market evaluation. New Chinese shot blasting machines are also more effective and productive than many older Western machines.

Why This Discrepancy?

The answer is **productivity**. The key technical characteristics of steel abrasives (which comprise 90% of metallic abrasives) have remained the same over the past decades. There were no leaps in quality nor in their production process and composition. Conversely, a shot blasting machine made in the in the past five years has improved tremendously compared to one manufactured 10 or 20 years ago. The new machines are computer driven and have high-speed wheels, innovative nozzles, improved wear-resistant parts, simpler maintenance requirements, finely tuned separators, and more.

Why Productivity has Increased

It is clear that the speed of blasting is a key factor of productivity and has a direct impact on cutting costs (less fixed and variable costs per part). This is precisely what new machines achieve: Higher output and enhanced productivity along with better industrial control, especially in maintaining and recycling the operating mix. The new generation of turbines cut maintenance costs even more because of the fast

and secure changing of their blades. The same phenomenon takes place with new cars. We enjoy a higher mile-per-gallon of fuel in a new car than one only a few years older. This is observed in all industrial processes.

If we can assume that there is a stable production of products such as cars, ships, railcars and pipes, the abrasives consumption goes down by 0.5% each year (outside China). As the annual replacement rate of new machines is about 4% (an average life of 25 years), this translates into:

1) Year one: 100% of the machines generate an index of 100 in abrasives consumption.
2) Year two: 96% of the previous machines are in operation, generating an index of consumption of 96; 4% of the machines are replaced; the total index of consumption is 99.5 (yearly gain of productivity of 0.5%).

This means that 4% of the machines generate 3.5% of the consumption. In other words, these new machines consume 12.5% less than the old ones (0.5 divided by 4).

The two perspectives, one with and one without China, stress that the more new machines, the more the consumption of abrasive drops. Conversely, a low rate of machine replacement means stable consumption patterns. Many Shot Peener readers observed this phenomenon when American or European foundries and forges relocated to emerging countries where new machines were installed in new facilities and their consumption of abrasives shrunk significantly.

Conclusion

- The shot-blasting machines industry is instrumental in raising the industrial productivity of the surface preparation sector.
- New shot-blasting machines can cut abrasive consumption by a two-digit figure.
- Shot-blasting machines manufacturers should be pro-active and push their customers to buy new machines based on a fast return on investment driven by a cost reduction.

WORLD, INCLUDING CHINA		2004	2012	8 Years Growth	Annual Growth
Metallic Abrasives (All Applications)	000's metric tons	1,330	1,450		
Granite Sawing	000's metric tons	215	160		
Metallic Abrasives in Shot Blasting	000's metric tons	**1,115**	**1,290**	**15.70%**	**1.84%**
Vehicle Global Production - Source: OICA[1]	000's units	64,496	84,208	30.56%	3.39%
Apparent Steel Use (ASU) - Source: Worldsteel.org	000's metric tons	973,999	1,432,182	47.04%	4.93%
Combined Growth of Shot-Blasting Applications	**2/3 ASU, 1/3 Automotive**			**41.54%**	**4.43%**
Discrepancy Between the Growth of Metallic Abrasives and the Growth of the Outlets				**25.84%**	**2.59%**

WORLD, EXCLUDING CHINA		2004	2012	8 years Growth	Annual Growth
Metallic Abrasives for Shot Blasting	000's metric tons	1,115	1,290	15.70%	
Metallic Abrasives in China	000's metric tons	190	308		
Metallic Abrasives Market, Excluding China	000's metric tons	**925**	**982**	**6.16%**	**0.75%**
Vehicle Global Production Excluding China Source: OICA[1]	000's units	59,262	64,936	9.57%	1.15%
Apparent Steel Use (ASU), Excluding China Source: Worldsteel.org	000's metric tons	698,180	772,122	10.59%	1.27%
Combined Growth of Shot-Blasting Applications	**2/3 ASU, 1/3 Automotive**			**10.25%**	**1.23%**
Discrepancy Between the Growth of Metallic Abrasives and the Growth of the Outlets				**4.09%**	**0.48%**

1) OICA stands for Organisation Internationale des Constructeurs d'Automobiles. This International Organization of Motor Vehicle Manufacturers was founded in Paris in 1919.

The Spring Manufacturers Institute (SMI) Launches SMI Metal Engineering eXpo

THE SPRING MANUFACTURERS INSTITUTE (SMI) has announced the launch of the SMI Metal Engineering eXpo™ at the Charlotte Convention Center in Charlotte, North Carolina. The inaugural event for the engineered spring and precision metal components industries will take place October 20-22, 2015.

According to SMI president Hap Porter, the SMI Metal Engineering eXpo will not only attract members of the North American spring and wire forming industry but participants from South America, Europe, Asia and Australia. A key component of the new expo is a technical symposium for individuals and companies to share their knowledge and expertise on a variety of topics surrounding the design, engineering and production of springs, wire forms and stampings. The show will also include vendors displaying a vast array of machinery to produce these items, along with wire suppliers and exhibitors representing all facets of manufacturing from insurance to machinery to ERP systems and more.

"The launch of the SMI Metal Engineering eXpo came in direct response to a strategic planning process that SMI undertook and adopted in 2013," said Porter, who is also the president and COO of SEI MetalTek. "The need for a show like this was due to member interest, especially among springmakers who wanted help solving complex engineering challenges. With a forum where technical questions can be answered, this event will go a long way toward elevating industry knowledge."

Dan Sceli, president and CEO of Peterson Spring, is serving as the chairman of SMI's newly formed trade show committee that is providing direction in launching the show. The committee is made up of SMI member springmakers, associate member suppliers and SMI executive director, Lynne Carr.

The Charlotte Convention Center opened in 1995 as a venue for conventions, trade shows, banquets and theater-style conferences, attracting more than half a million visitors each year. The Westin Charlotte Hotel is conveniently located next door to the Charlotte Convention Center, and will serve as the headquarters hotel for the SMI Metal Engineering eXpo. Based in the Chicago area, the Spring Manufacturers Institute (SMI) started in 1933 and embraces its mission statement of: "Serving, supporting and educating North American precision spring manufacturers in their pursuit of competitiveness in world markets."

For more information about the SMI Metal Engineering eXpo, visit the website for the show at www.metalengineeringexpo.org or contact SMI at 630-495-8588, email: lynne@smihq.org, or visit www.smihq.org.

WHO SHOULD ATTEND?

Audience: SMI Members, Spring Manufacturers, Wire Form Manufacturers, OEMs, Customers of spring, wire and stamping manufacturers

Job Titles: CEOs, Engineers, Buyers, Plant Managers, Floor Managers

WHO SHOULD EXHIBIT?

The exhibit floor will be the place for OEMs, spring manufacturers, distributors, coiling, grinding, shot peening and wire forming companies to showcase the newest equipment and latest technologies to key decision makers in the industry.

About Spring Manufacturers Institute

Founded in 1933, the Spring Manufacturers Institute (SMI) is an association of companies that manufacture springs, and their associate suppliers. The members of SMI work together to meet the key issues of the industry worldwide: quality, materials, technology, and government regulations. SMI provides many services including a quarterly magazine, Springs, a variety of technical publications, spring design software, industry data, seminars, meetings, safety and regulatory compliance, and technical assistance. For more information, visit www.smihq.org.

TOYO SEIKO OPENS FACILITY IN NORTH AMERICA

TOYO SEIKO CO., LTD. has established TOYO SEIKO NORTH AMERICA INC. in South Bend, Indiana in April 2014. TOYO SEIKO NORTH AMERICA INC. is the direct distributing arm of TOYO SEIKO CO., LTD. and TOYO SEIKO (Thailand) CO., LTD., a manufacturer of superior quality cut wire and conditioned cut wire shot for shot peening.

Since 1990, TOYO SEIKO has distributed their conditioned cut wire shot in North America in cooperation with a local manufacturer. Now, because of the growth of the automobile business in North America—the main user of conditioned cut wire shot—TOYO SEIKO will strengthen its sales system through a locally incorporated company.

South Bend is at the junction of three interstate systems and four national highways. TOYO SEIKO NORTH AMERICA INC. utilizes this strategic location to provide exceptional service in distributing the superior quality TOYO SEIKO cut wire shot.

The main target of TOYO SEIKO NORTH AMERICA INC. will be the automobile and aerospace business in North America, and the company will actively work to develop new customers. The line of business will be not only shot peening media but also the Coverage Checker, which is a measuring device of shot peening coverage. TOYO SEIKO will also seek ways to sell inspection equipment, now being developed in Japan, and to locally manufacture shot in the future.

In March 2014, The Ministry of Economy, Trade and Industry (METI) selected 100 Japanese companies as "Global Niche Top Companies Selection 100," and TOYO SEIKO was selected as one. These companies are those who set out to capture global markets, secure high market share in niche sectors, and carry out healthy management.

TOYO SEIKO products are specified by all major automotive and aerospace companies. If you are a current TOYO SEIKO cut shot wire consumer, TOYO SEIKO NORTH AMERICA INC. looks forward to continuing to meet and exceed your expectations. If you are interested in becoming a valued customer of TOYO SEIKO NORTH AMERICA INC., a knowledgeable staff will explain in detail the benefits and advantages of TOYO SEIKO shot peening products. Please call (574) 288-2000 or send an email to sales@Toyoseiko-na.com.

RYAN CLAY JOINS ERVIN INDUSTRIES

ERVIN INDUSTRIES is pleased to announce Ryan Clay has joined the company as Sales Manager and will be working at the Corporate Office in Ann Arbor, Michigan.

Mr. Clay will work with the Ervin Distributor Sales Group and Direct Representatives. He will assist with sales, marketing and application assistance of AMASTEEL and AMACAST products.

Mr. Clay comes to Ervin Industries from the Timken Corporation as a Sales and Service Engineer in the Bearing Division. He has eight years of experience in the industrial marketplace and his engineering background will be an excellent asset in surface preparation and shot peening applications.

SINTO AMERICA ACQUIRES TECHNICAL METAL FINISHING

On June 1, 2014, Sinto America Inc, acquired privately owned Technical Metal Finishing (TMF) located in Wallingford, Connecticut. TMF is a technology-based surface enhancement company servicing advanced manufacturing for more than 20 Years. TMF has an impressive customer base that includes the largest and most respected Aerospace, Medical and Industrial Gas Turbine companies in the world. TMF is certified for Nadcap AS9100, ISO 9001:2008, and ISO 13485:2003.

TMF's core competencies will accelerate Sinto America's strong commitment to growing the company's surface treatment services in North America.

Bill Traeger, Vice President of Sinto Surface Treatment, stated. "The addition of TMF to our surface treatment family enables us to leverage our current technology with a synergistic customer base while adding new industries to our expanding portfolio. The enhanced super finishing capabilities of TMF will enable us to further promote our strategic value proposition of providing exceptional customer service to our customers."

Stephan Rösler Dedicates New Manufacturing Facility in Pune, India

WITH A TRADITIONAL INDIAN CEREMONY, the employees of Rösler India, together with Mr. Stephan Rösler—majority shareholder and chairman—and Mr. Sandeep Gulati— partner in this joint venture and managing director of Acton Finishing Ltd. UK – celebrated the official opening of the Rösler subsidiary in Pune in the Maharashtra district.

This new manufacturing facility with attached office space in Pune represents a significant expansion of Rösler operations in India that includes Rosler SurfaceTech Pvt, Ltd. in Bangalore. In the new premises with a manufacturing area under roof of 2,680 m² (26,800 sq. ft.), including a test lab and job shop as well as office space of 240 m² (2,400 sq. ft.) standard shot blast machines and rotary vibrators will be manufactured. The first pieces of equipment have already been produced.

It is planned to exclusively utilize the German equipment designs and adapt the manufacturing process to the Indian facility including the search for local component suppliers. This is an important strategic step with the goal to successfully compete with Indian low-cost equipment suppliers and to gain a dominant market position in India and Southeast Asia. The Rösler quality combined with a cost efficient production facility in Pune is an ideal springboard to successfully exploit the huge market potential in India and surrounding countries. Within the next few months Rösler India will expand its staff to over 50 employees.

Mr. Stephan Rösler and Mr. Sandeep Gulati celebrate the official opening of the Rösler subsidiary in Pune, India.

Production of the rst pieces of standard equipment has been successfully completed in the Pune, India facility.

Progressive SURFACE

PRIMS Pro®

More efficient parts processing? Procisely!®

PRIMS Pro® gives engineers and operators the most advanced and flexible process controller ever. **PRIMS Pro®** is Windows-based and **procisely** customized for your shot peening operations.

Part & program manager

- ***Queue*** *parts before processing, or while others process*
- ***Search*** *by easily sorting through large quantities of parts*
- ***Select*** *and define multiple motion control or surface functions*
- ***Modify*** *or review part programs*

Preventive maintenance

- ***Auto-sort*** *based on next item required*
- ***All-in-one*** *maintenance scheduler, historian, and advisor*

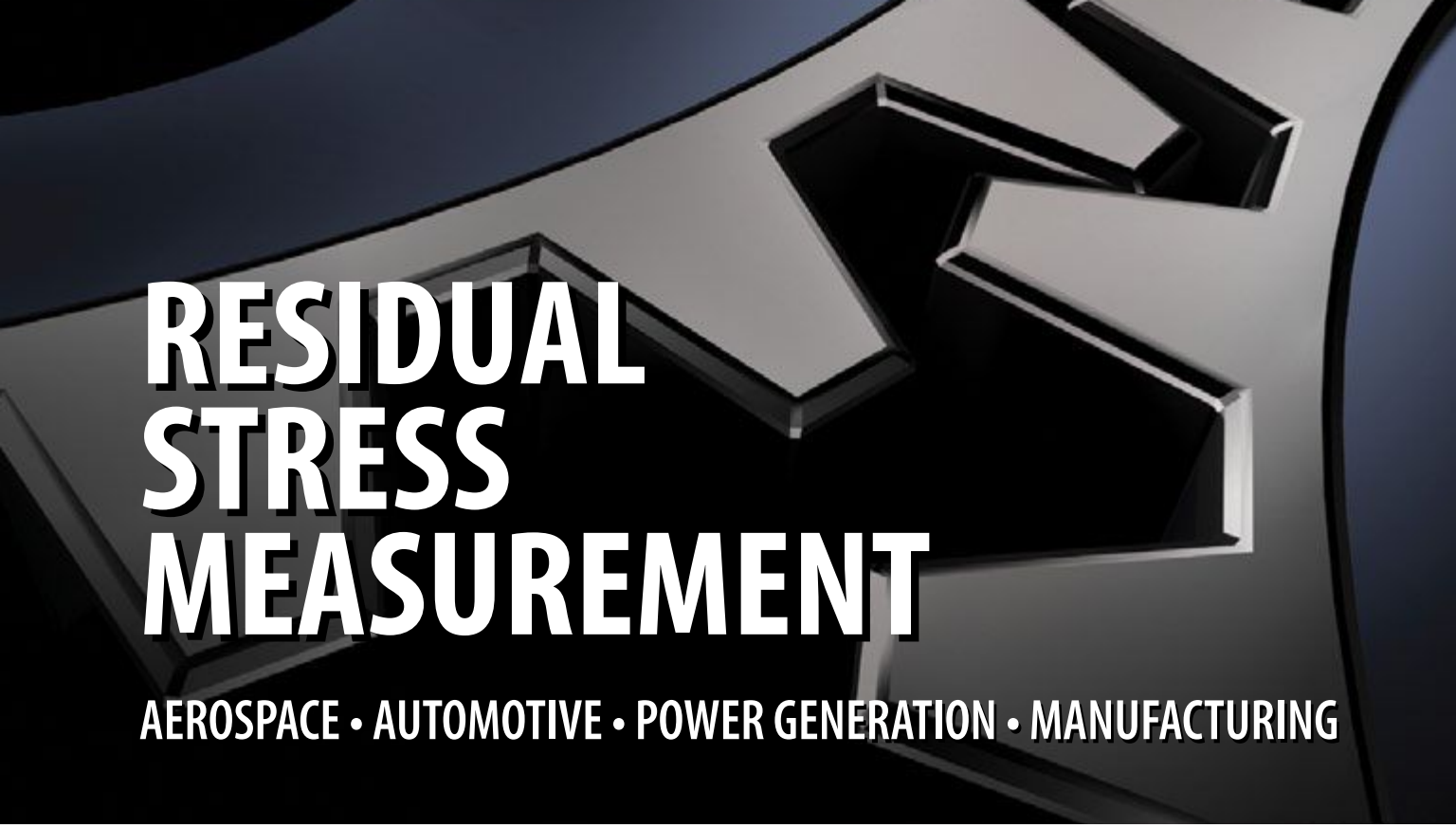
Multi-level security system

- ***Customize*** *permission levels by user log-in*
- ***Control*** *modifications to process parameters and part data*
- ***Limit*** *who can reset PM items or run alarms*

PRIMS Pro automates process control, monitoring, and data-logging for key parameters. It's the ideal monitoring software for production, overhaul and repair, and R&D.

Learn more at:

progressivesurface.com



RESIDUAL STRESS MEASUREMENT

AEROSPACE • AUTOMOTIVE • POWER GENERATION • MANUFACTURING

Reduce costs and improve quality.

Residual stress plays such a critical role in the fatigue life, cracking and distortion of components, that its characterization is more important than ever. In today's tough economic times, X-ray Diffraction (XRD) residual stress measurement can both improve quality and help lower component cost by reducing scrap rates, shortening design cycles and ensuring full component life.

Our comprehensive line of XRD residual stress measurement systems and full service laboratories have the accuracy, speed, technology and knowledge to keep your product perfect right from the start.

Automated NDT Systems & Service
PROTO
Manufacturing

LABORATORY SERVICES

FIELD SERVICES

PORTABLE XRD SYSTEMS

LABORATORY XRD SYSTEMS

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

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

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

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