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The Shot Peener

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

The Product & Services Issue

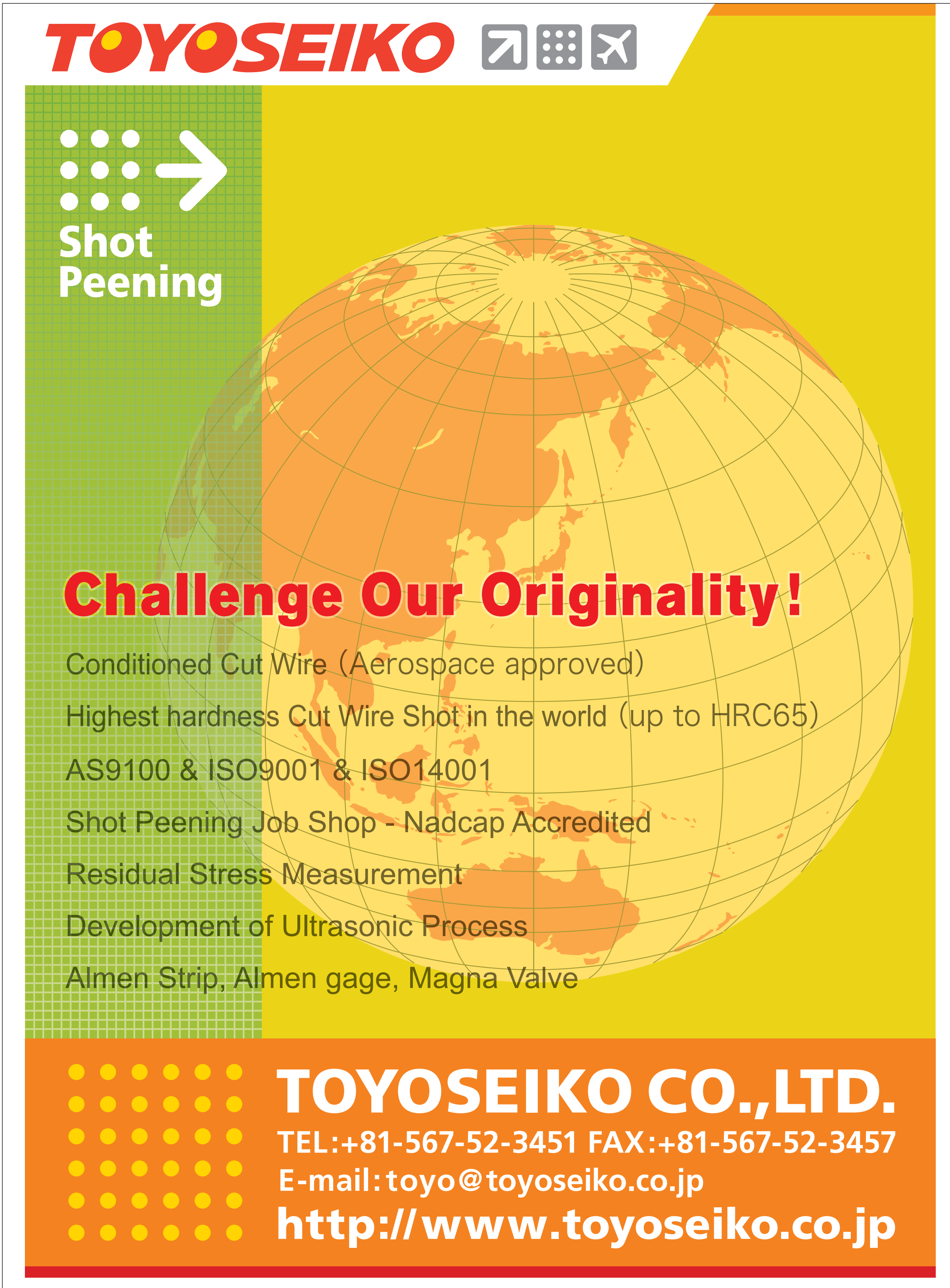
A sampling of new and unique products and services in surface finishing

Peening Process Control and Operator Interface

X-Ray Diffraction

Coverage Measurement

Application Validation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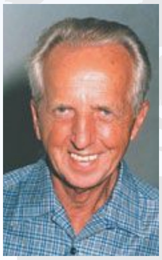
The Product & Services Issue



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

Market Development

THIS SHOT PEENER is a sampling of the new and unique products and services in our industry. If you feel like your company was left out after you read the magazine, don't. My associate editor wouldn't even entertain the idea of getting a 400-page magazine out in three months so we're going to include additional success stories in upcoming issues.

If you still need to feel better, Electronics Inc. doesn't have an article in this issue either. That's because one of our most exciting ventures isn't a success story yet. Introducing valves and controllers for automotive and aerospace applications isn't new to us but now we're trying to take on the medical implant industry. It's a whole new ball game.

JACK CHAMPAIGNE

While testing shot peening for tissue adhesion, we discovered a shot peening process that reduces bacteria growth in medical implants. Infections after implant surgery are a big problem for patients but in keeping with the sports analogy, we weren't sure how to get into the medical implant manufacturing game with our research results. We didn't know the key players, much less the rules. What we do know is shot peening and how to engage the services of professionals to get us where we want to go. And if we don't win this game, we have a Plan B.

Many of us in the shot peening industry should have a plan to join the "shot peening for medical implants" game. It's a considerable market because the demand for joint replacements, spine implants, and pacemakers is going to grow as the baby boomer generation ages. Our SAE committee is working on a spec for medical implants that will go a long way in helping us. I'll extend an invitation to anyone that wants to contribute to, and benefit from, the work of this committee. Send me an email at jack.champaigne@electronics-inc.com.

As a shameless plug for this magazine and Electronic Inc.'s shot peening workshops and trade shows, both are attracting more medical implant manufacturers. EI's successful entry into this game will make more shot peening fans for everyone. We'll keep you posted.

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PRODUCT NEWS: PROCESS CONTROL & OPERATOR INTERFACE

Jim Whalen | Vice President Sales and Marketing | Progressive Surface

A New Standard for Peening Process Control and Operator Interface

SHOT PEENING has been around for over 75 years and for the most part, the way the process is characterized and controlled has remained unchanged since the beginning. While closed loop devices have been developed to control key input variables, until recently the only way to measure the key output variable of intensity was with the Almen strip.

Process Development Process Today

As shot peen users know, developing a saturation curve for an actual component is a trial-and-error process that can be quite time consuming. A set of process parameters is selected based on the specified media and size believed to provide the required intensity. Peening trials at various exposure times are performed to gather enough arc heights to plot a saturation curve. If the resultant intensity or cycle times are not within the specification range, the process is repeated until the desired intensity is achieved.

An optimized method has been needed that allows users to quickly dial in the required intensity in a fraction of the time it currently takes.

Traditional Process Control and Troubleshooting

Controlling a developed shot peening process is similar but, instead of creating a saturation curve, the saturation point is validated at some normal frequency using Almen strips. These frequencies vary from once a shift to as often as before each different part type is run. In the case of small lot sizes, running Almen verification strips can take as long as running a part, adding cycle time and cost with little added value. What's worse, if an Almen strip falls outside of the approved range, the process engineer is left with hours of troubleshooting to find the root cause of the process change.

ShotMeter G3

ShotMeter G3, a joint solution provided by Progressive Surface and Tecnar Automation, uses a simple method of particle illumination and two electro-optical sensors of a known spacing to sense particles as they exit the shot peening nozzle. The signals from the two sensors are compared and the resulting phase shift is used to calculate velocity, with accuracy within 1%. There are currently more than 30 ShotMeters in use worldwide.

PRIMS Pro with Integrated ShotMeter

The ShotMeter system is offered as a portable configuration, or integrated with PRIMS Pro, Progressive's process control and integrated monitoring system. Both configurations provide the user with adjustable setpoints and alarms for shot velocity.

Processes Developed in Days, Not Weeks!

A major aircraft engine manufacturer recently benefitted from reduced development time, thanks to the ShotMeter. The manufacturer purchased a Progressive Surface 6-axis robotic shot peening system and required process recipes for five different intensity ranges at three different impingement angles with three different nozzles. Utilizing traditional methods, developing the 45 distinct saturation curves would have taken several weeks to complete. But with the use of previously developed process models and the ShotMeter, preparing a new development methodology consisted of a few simple steps.

Step 1. Collect a velocity fingerprint for the machine using the velocity profile factors that are unique to that machine (for example, hose length and diameter).

Step 2. Enter the desired angle of impingement and required intensity into our empirically developed process model for the specific media size and type. The output of this model is a target velocity needed to achieve the required intensity.

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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:

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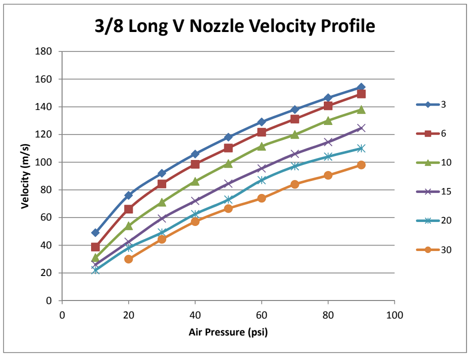
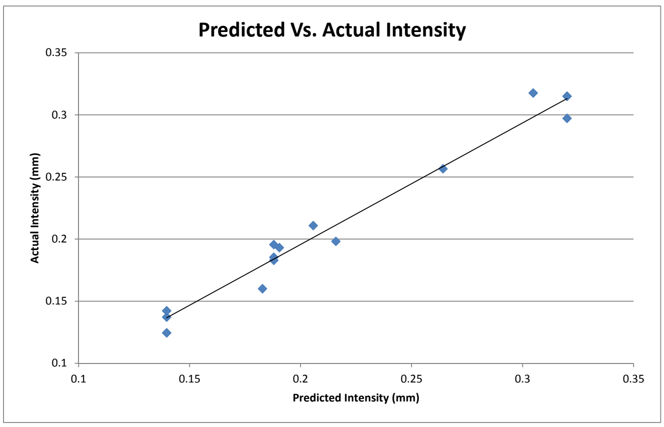


Machine Fingerprint Chart – Velocity vs Air Pressure



Accuracy of Using the ShotMeter as a Development Tool

Once the target velocity for a particular intensity is known, the process engineer uses the fingerprint data developed in Step 1 to select his air pressure and shot flow.

Using this methodology, no trial and error was needed. We reduced the time required to complete this task from several weeks to just a few days. The customer was able to take delivery of their machine weeks earlier, and was presented with a process model and machine fingerprint to use now and in the future.

ShotMeter as a Troubleshooting Tool

Progressive has delivered ShotMeters to many different customers who use it for research, process characterization and development. Many customers will use the ShotMeter to perform periodic machine health checks or calibrations. This data is used to set nozzle and hose change intervals as well as to verify that air pressure controllers and their closed loop media flow controllers are still working correctly.

A large aerospace customer discovered the advantages of the ShotMeter when they were forced to shut their machine down in order to troubleshoot a problem. They tried changing hoses, nozzles, and shot flow controllers, and could not figure out why their Almen verification strips were not within the required specification. A Progressive Surface service engineer used ShotMeter to check baseline conditions using the velocity fingerprint. With the ShotMeter's help he quickly determined that the machine fingerprint matched, which narrowed the possible causes considerably, to either the media or the Almen strip itself. Since the media had been working without problem in the machine for a long time, it was determined that the root cause of the problem was the Almen strip. Once a new lot of Almen strips was used, the intensities came back to where they were supposed to be. Unfortunately this entire episode cost our customer a couple weeks of lost production. The solution to their problem was quite simple, and easily determined once the ShotMeter was employed as a troubleshooting tool.

Integration with PRIMS Pro

Another advantage of the ShotMeter is its ability to integrate with machine process monitoring software. PRIMS Pro, Progressive's updated software released earlier this year, has many new features including enhanced user-friendly graphics, part queuing, expanded process/image association for individual parts, alarms with diagnostics, and simplified scheduling and tracking of preventive maintenance. To date we have several customers in varying industries, including medical, aircraft engine and airframe, enjoying the improved level of in-process control offered by an integrated ShotMeter.

Before and after each part is processed, the nozzle is moved in front of the ShotMeter sensor head and the velocity is measured, recorded with the process record for that part, and checked against the pre-established process limits. This ensures that the process is consistent and the same as previously determined. If the velocity is recorded outside of the approved range, the part processing is halted and maintenance is called to correct the problem. If the velocity is out of range at the end of the process, then quality is alerted and the part quarantined until proper engineering disposition is made. This new level of process control is becoming the standard for today's lean, quality-driven manufacturing environment.

Conclusions

Since its introduction the marketplace, ShotMeter users have realized its many benefits including:

- Significant reduction in process development time
- Useful aid in troubleshooting process issues, getting machines back to production sooner
- New process monitoring tool in controlling the process beyond the Almen strip

The cost of the ShotMeter is usually recouped very shortly after it is purchased. If you are interested in learning more about the ShotMeter, visit our web site www.progressivesurface.com or contact us at sales@progressivesurface.com. Demo and rental units are available.

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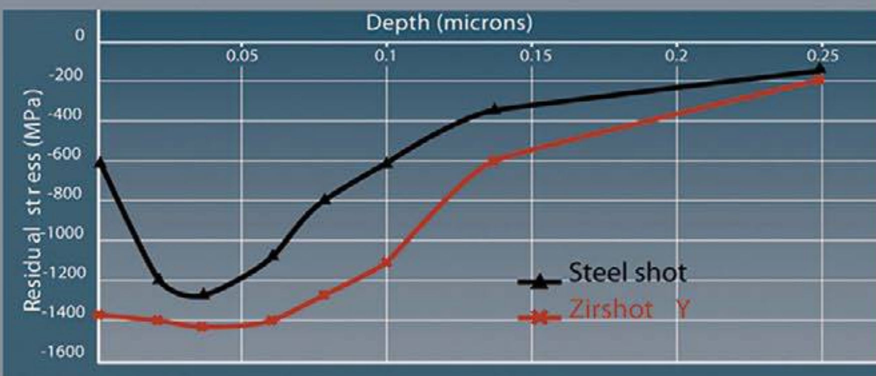

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Beth Matlock | Senior Materials Engineer | TEC

X-Ray Diffraction Impacted by TEC's Contribution

History

Wilhelm Röntgen discovered x-rays in 1895. I wonder what he would think if he knew the number of people's lives he impacted. In 1912, Sir William Henry Bragg gave us the equation for x-ray diffraction. X-ray diffraction is the scattering of x-rays by crystal atoms, producing a diffraction pattern that yields information about the structure of the crystal, such as the distance between the planes of atoms.

Now we could do some really useful things with Röntgen's x-rays! As we travel through history, the next exciting discovery for me was residual stress measurement in 1925. My son, who often accompanies me when I give technical presentations for TEC, proclaimed that I should know all about this discovery since I was probably there when it happened. (My dad didn't come along until 1927, and my mom made the scene in 1930.) Over the course of 30 years, we were given the basics for changing the world—the world of residual stress measurement. It took about another 50 years to see the next big change in this field. In the 70s, position-sensitive detectors were developed that could identify an entire diffraction peak without having to step scan through the large angular range required by other detectors. Position-sensitive detectors gave rise to the small, portable systems we know and love today.

Technicians with Warren-Robbins and TEC are measuring the fuselage on a C-5 transport with a TEC 1630. The computer is recording and analyzing data for rapid and precise results.

X-Ray Diffraction Residual Stress Measurement

To understand residual stress measurements by x-ray diffraction, we need to understand residual stresses. If I push, pull, twist, or bend a part, I'm putting an applied load on the part. When I let go, if I've been successful in plastically deforming the part by pushing or pulling, there will be new residual stresses left in my part. Let's say you put a paperclip on a few pages of paper. The paperclip is basically in its original shape with no significant increase in residual stresses when you remove it from the papers. However, if I then need that paperclip to retrieve Playdough from my computer keyboard, I can plastically deform it into a hook. The process of plastically deforming the paperclip has now changed its residual stresses. And when I imparted residual stresses into the paperclip, I changed it at an atomic level—I changed the distance between the paperclip's atoms.

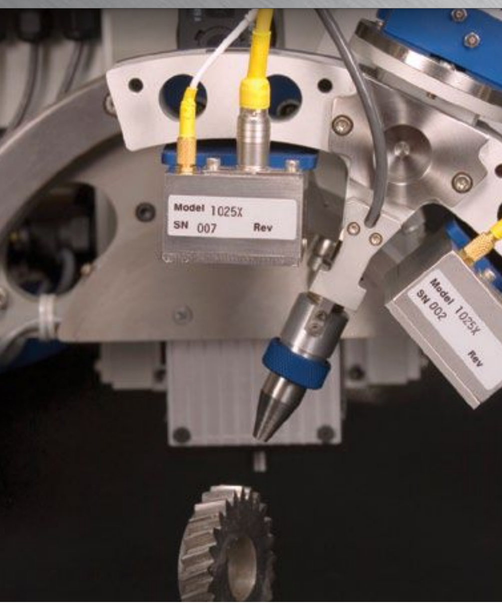
X-rays are useful because they can tell us how much distance lies between atoms of the paperclip. Think of these atoms as lying in sheets stacked on top of each other, then imagine these sheets as being connected with springs and that you can change the distance between the sheets by pushing or pulling on the outer layers. X-rays don't care if you push or pull, they simply measure the distance between the sheets. I can tell how much residual stress is in my paperclip simply by measuring the distance between the sheets. If the sheets are pushed together, we have a compressive stress. If the sheets are pulled apart, we have a tensile stress. In the real world, tensile stresses are generally bad since they are pulling things apart. Compressive stresses are usually good because they tend to hold parts together. We can measure both types of stresses using x-ray diffraction.

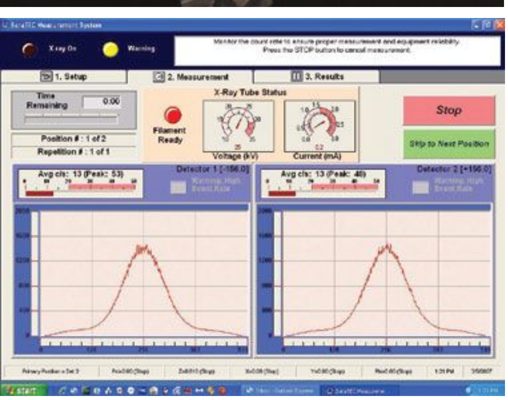
TEC's Role in the Industry

Being at the right place at the right time has advantages. TEC was a leader in building position-sensitive detectors when Northwestern University was developing PARS (Portable Apparatus for Residual Stress). TEC obtained the manufacturing rights from Northwestern University to develop a commercial, portable x-ray diffraction system. Not only did we then develop a commercial system, but we eliminated the guitar strap used by the graduate students to hold the system in place while making measurements. Radiation safety officers around the world probably breathed a sigh of relief with this improvement. The software was developed so that even a Ph.D. could operate it.

After potential users were surveyed, TEC decided that a portable diffractometer with a long umbilical cord would best serve the military and commercial customers. The umbilical cord was attached to a transportable cart, affectionately known as the tank. Our tank was designed to withstand a nuclear blast or airport baggage handlers, whichever was deemed the most destructive. Actually, we wanted a rugged design that would survive the environment of a Naval Air Depot or indus-

Materials Testing Services





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trial complex. We may have outdone ourselves since our first commercial unit, delivered in April 1984, is still working today at Redstone Arsenal.

We spent much of the 1980s refining our 1600 series in an applications lab. We teamed with several well-known leaders in residual stress and retained austenite measurements to develop systems that would take what the real world would throw at it. Industry and the military would send us samples to see what new and exciting heights could be reached with a portable system. Some of the samples required cherry pickers and scaffolding to reach these heights. We eventually plunged to great depths when we went underground to inspect a structure underneath a dam. While developing new applications, we were constantly asked if we offered measurement services to compliment our products. In 1989, our services lab was inaugurated with a marathon trip to measure the space shuttle's solid rocket booster casing. Our crew of four with our trusty 1610 system worked round the clock for a couple of weeks to measure the infamous tang and clevis areas of the casing.

In the mid-90s, TEC embarked upon a major design change to the 1600 series. The TEC 4000 was born out of this effort. The basis for the TEC 4000 was to do everything the 1600 could do plus additional applications. Nine different peak-fitting routines was just the start. The 4000 could operate equally well in two orientations, and much of the operation was automated. We have found that even the computer-challenged individual was able to successfully operate this new system.

As we entered the 21st century, TEC decided to make another giant leap and developed MAX (Miniature Apparatus for X-rays). MAX is so small it can fit inside a six-inch opening. It's almost as fast as a speeding bullet. We haven't tried to see if it can leap tall buildings with a single bound, but its residual stress measuring capability is just as amazing. The progression of the 1600 to the 4000 to MAX is similar to the progression of a mainframe computer to a desktop to an iPad.

Practical Applications

When x-ray diffraction residual stress measurements were first made on laboratory-type diffractometers, one had to cut a quarter-sized plug out of the part, take it to the lab, and then wait eight hours or so to get a result. Unfortunately, cutting the plug out of the part not only destroyed the part, but probably relieved most of the stresses that we needed to measure. When the centerless diffractometers with position-sensitive detectors were invented, parts could be measured without sectioning. Not only did we save the part, but we could measure stresses in a fraction of the time—minutes instead of hours. Field measurements were also possible, which opened up the door for a truly useful non-destructive evaluation tool. So, where have we gone with this unique capability?

The aerospace and automotive industries have a real need for these measurements. Both groups have engines with moving parts, lots of bearings, transmissions, and structural members. These parts have been machined, cast, welded, forged, rolled or ground along with other manufacturing processes. Some of the parts have been carburized, nitrided, coated, anodized, heat treated or otherwise enhanced. A good portion of the parts have been cold worked, burnished, or shot peened. Each of these processes changes the residual stress in the part.

When we fly or drive, we prefer that our planes and vehicles have those good compressive stresses in all the critical places to make sure we arrive at our destination safely. Not only are we able to measure the parts when they are manufactured, but in many cases, we can also measure the parts after they are assembled. After all, if there is a suspect part, who wants to dismantle the entire assembly just to see if an improperly processed part accidently made it onboard?

Many failures can be attributed to bad stresses at or near the surface of the part. Usually these stresses are tensile ("pulling apart") stresses. Fatigue, stress-corrosion cracking, and overload are examples of failures where tensile stresses are generally the culprit. Luckily, we can often do something to the part to change the tensile stresses into the more desirable compressive stresses.

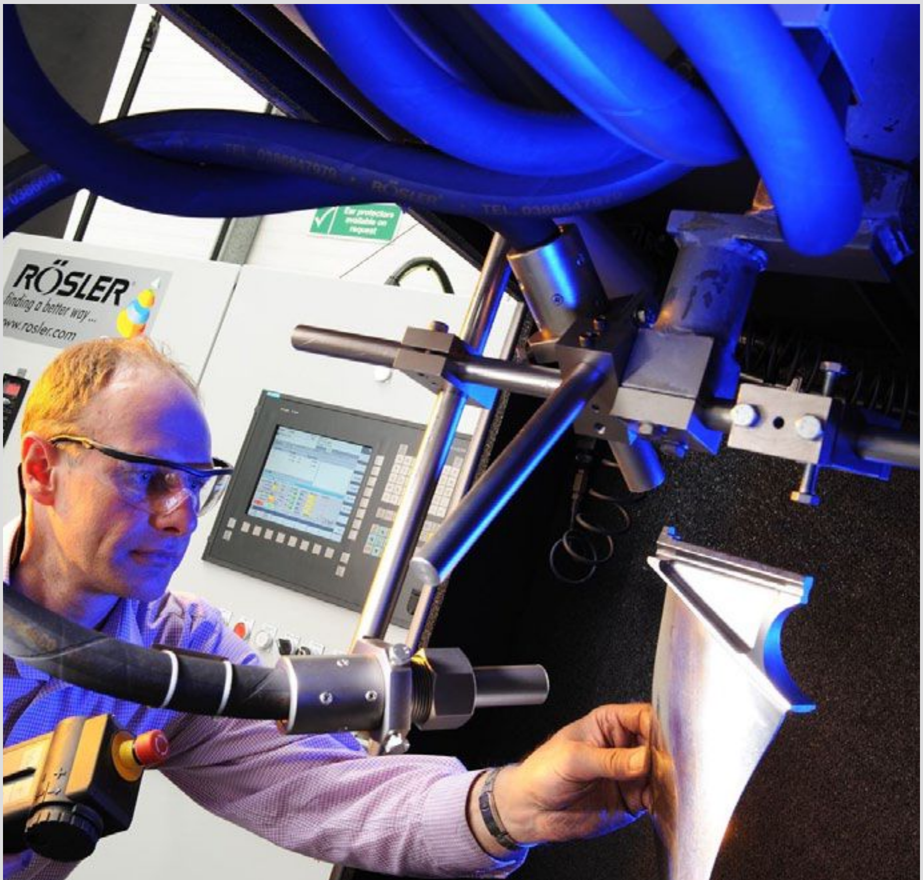
A favorite method for *The Shot Peener* magazine's readers to change bad tensile stresses into good compressive stresses is shot peening. Shot peening is the process of blasting a part with small beads of metal or ceramic in a controlled manner to put a sample's outer layers into compression. Because the beads hit the surface much like a hail stone hits your car hood, the stresses are uniform in all directions around the indentation. In other words, a very, very small crater is formed and the distance from the bottom of the crater to the top rim is the same all the way around the crater.

Let's use the analogy from the top. When the shot hits the sample, the springs holding the sheets of atoms gets so tightly compressed that they can only spring back part way. Because the springs aren't the same height as before shot peening, the sample will show a compressive stress. Not only are the top layers of atoms affected, but many layers beneath the top are also in compression. Because the atoms in the very top sheet don't have a layer of atoms above them, they can relax a bit more than the layers that have atoms above and below. When we use x-rays to measure the stress at and near the surface of a shot peened part, we will find that the compressive stresses at the surface are not as compressive as the stresses just beneath the surface. It is often this profile of compressive stresses at the surface followed by more compression just beneath the surface that protects a part from failures.

Conclusion

X-ray diffraction has come a long way since Röntgen first discovered those powerful rays. Thanks to the development of x-ray diffraction followed by the development of the residual stress measurement technique, we have learned how to look at the stresses that can cause or prevent failures. TEC, with its roots in position-sensitive detectors, has developed a line of diffraction systems that has allowed Man (or Woman) to boldly go where no x-rays have gone before. TEC continues to search for the truth in x-ray diffraction residual stress measurements.

Come and share the journey with us.



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Kanehisa Hattori | General Manager Surface Treatment and R&D Division | Toyo Seiko

Coverage Measurement Innovation

From Determination to Numerical Analysis

QUALITY ASSURANCE for shot peened parts is mainly materialized with inspection of arc height intensity and coverage, or roughness, residual stress or hardness. As for appropriate coverage judgment, personnel have to be well-educated and experienced because accuracy depends on individual capability. If coverage testing is performed with insufficient accuracy, it will undermine the value of coverage as a guarantee of quality.

Two years ago Toyo Seiko Co., Ltd. developed a coverage measurement device called the Coverage Checker™. Inconvenience in the calibration process has prevented its spread. In this report, a simplified calibration process is explained and two types of calibration line for flat and curved surface are enumerated.

MAKING A RECIPE

Coverage Checker needs calibration data for the correlation between the given coverage percentages measured visually and the pixel counts of binarized image. This calibration data is called a "Recipe." Before making a Recipe, a complete coverage (100% coverage) sample and more than one incomplete coverage (50-90%) samples are necessary.

A Recipe process consists of setting measurement conditions and creating a calibration line. With the latest Coverage Checker, setting conditions are simplified and easier to understand. Setting measurement conditions consist of three steps: exposure value, threshold and minimum area. The procedures respectively for a flat surface and a curved surface are shown as below.

Setting Measurement Conditions for Flat Surface

The first step to making a Recipe is the exposure value has to be set with a complete coverage sample. In setting exposure value window (Fig.1), histogram of brightness can be expressed with a resolution of 256. While confirming this histogram, adjust exposure value to make the histogram peak a little bit lower than the middle value (127).

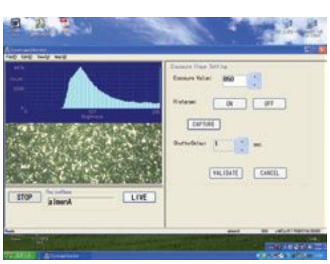

Fig.1 Setting exposure value window

Then, set the threshold that is a standard value for binarization to identify peened area and non-peened area. For threshold setting, an incomplete coverage sample shall be used.

In threshold setting window (Fig.2), choose sectional brightness graph. While confirming the graph, adjust the minimum value of threshold. Brightness on red line is shown in the window.

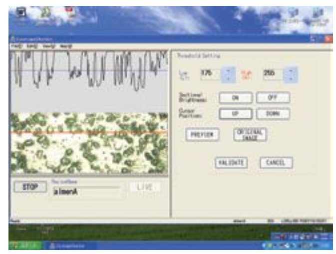

Fig.2 Setting threshold window

Since the center part of the peened dent will form a face parallel to the non-peened area, it will be captured white like the non-peened area. These areas are noise. Therefore, the area whose pixel number is less than certain level is omitted. In minimum area setting window (Fig.3), set the size to be eliminated from measurement object.

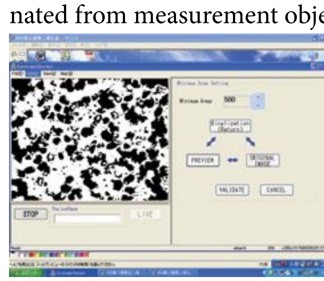

Fig.3 Minimum area setting window

Setting of measurement parameter is completed. Then with coverage samples visually inspected, the Recipe is made as shown in Fig.4 with five samples. Horizontal axis represents visual coverage percentage and vertical axis represents white pixel counts.

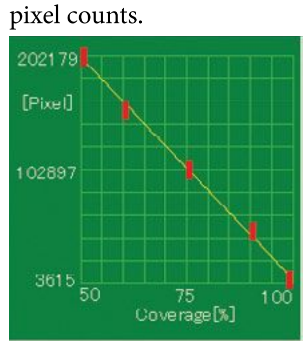

Fig.4 Recipe (calibration line) for flat surface

Setting Measurement Conditions for Curved Surface

A curved-surface image has a different characteristic than a flat surface. Non-peened area is captured black. As much as coverage value rises, white increases due to diffused reflec-

Coverage Measurement Device

*PC is not included

Easy USB connection to your PC

COVERAGE CHECKER

Coverage Measurement Device

*Device image

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.

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tion. A Recipe is made by focusing on this characteristic. First, exposure time is set. Like for the flat surface, exposure time is adjusted to make histogram peak close to the middle value (127) with a complete coverage sample. Example is shown in Fig. 5.

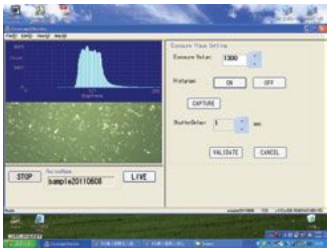

Fig.5 Setting exposure value window

Then, threshold value is set. For threshold setting, incomplete coverage sample is used. Sectional brightness graph is called. Set the low value of the threshold at the position that does not come in contact with the base curve of brightness. The example is shown in Fig.6.

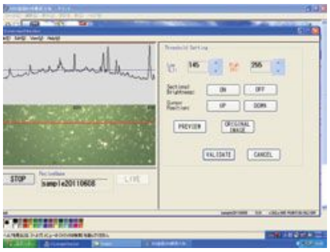

Fig.6 Picture of setting threshold for curved surface

For curved surface measurement, the minimum area is set in 100 pixels or less.

Setting of measurement parameter is completed. With coverage samples visually inspected, Recipe is made as shown in Fig.7. Differ from flat surface measurement, graph leans upward to right. Comparing to flat surface measurement, vertical range becomes narrow. The radius of the curved surface smaller, the range of pixel counts narrow then it effects measurement accuracy. Therefore, the radius of curvature to measure recommends more than 0.15″.

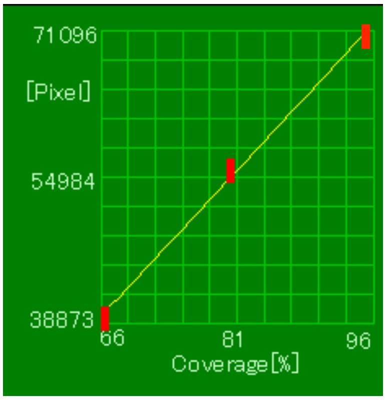

Fig.7 Recipe (calibration line) for curved surface

INTRODUCTION OF IMPROVED POINTS

Focus Adjustment Tool and Nozzle

With this tool, it is easier to adjust focus with good repeatability especially on curved surface, for example coil spring and stabilizer (made of round bar). Also the head of nozzle is improved to fit on curved surface. The appearance is shown in Fig.8. Focus adjustment processes are shown in Fig.9.

Fig.8 Focus adjustment tool and new nozzle

Fig. 9-1) Fix the position of Focus adjustment tool against surface to measure

Fig. 9-2) Adjust the nozzle length with Focus adjustment tool

Fig. 9-3) Measure the coverage

Saving Data and Installing the Program

Results that include capture image and Recipe name can be saved onto a hard disc. This will make daily quality control easier.

Coverage Checker software can be installed on Windows-based PCs with a CD-ROM provided in the new Coverage Checker set. The set includes the Coverage Checker, focus adjustment tool, nozzle and software CD-ROM. The software can be installed on an unlimited number of the customer's PCs.

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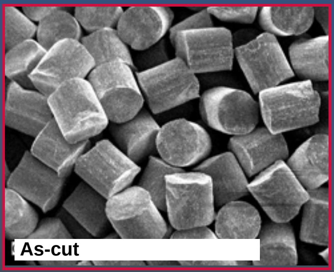
- **Lower Surface Contamination -** Cut Wire Shot doesn’t have an Iron Oxide coating or leave Iron Oxide residue - parts are cleaner and brighter.
- **Improved Part Life -** Parts exhibit higher and more consistent life than those peened with equivalent size and hardness cast steel shot.
- **Substantial 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.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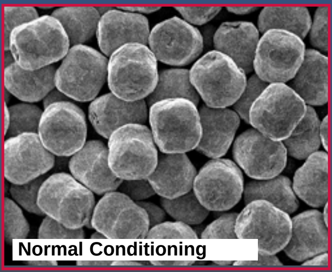
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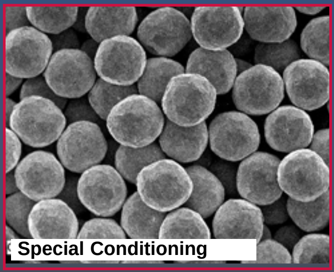
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PRODUCT NEWS: INDUSTRY OF THE FUTURE

Kumar Balan | Director, Global Technologies | Wheelabrator Group

Shaping the Industry of the Future

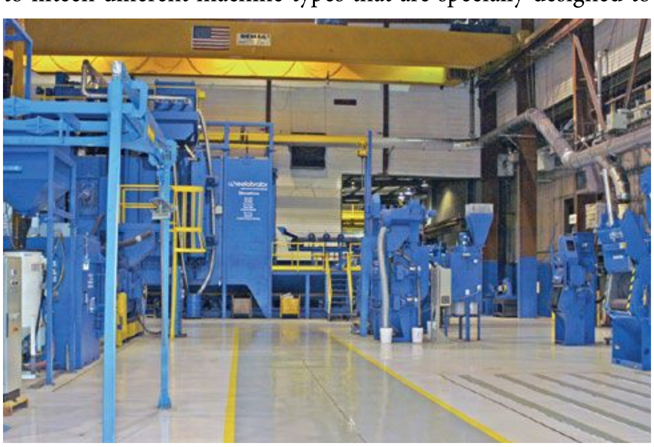
HOW DO YOU perceive the industry of the future? Are traditional processes going to be questioned and reformulated? These are some of our thoughts as we follow our daily routine activities and plan for the future. In our own process-oriented world of blast cleaning and shot peening, products will be made faster, cheaper, smarter, and safer. We must be capable of producing repeatable and reliable results with minimal environmental impact. Translated into more tangible terms, the time line between concept and commercialization will shrink for us all!

At Wheelabrator, we recognized this movement over the past decade and focused on innovation to help our customers adapt to this reality. Our research and development department got infused with a concentrated dose of adrenaline and became the cornerstone of equipment design, application validation and process development. The result was a rejuvenated "Application Validation" department.

How Does "Application Validation" Help?

Most OEMs work with custom applications on a regular basis. At the time of sale, it's the winning ***concept*** that gains approval, since a machine typically doesn't exist in a form suitable for validation. Variables that could have an impact on machine design are cycle time, media type, shape, size and velocity. Now, just imagine if we can, with reasonable accuracy, determine these variables in advance for your application? That's exactly what Application Validation does.

The North American Application Validation Center of Wheelabrator, one of five across the globe, is housed in a 25,000 square-foot facility in LaGrange, Georgia. The center is home to fifteen different machine types that are specially designed to cover almost every conceivable application in wheel and airblast systems. A potential customer walks in with a component to be peened or cleaned and leaves with specific information pertaining to media type, size, impact velocity, possible cycle time, intensity value, coverage and saturation time (in peening applications), part handling, fixtures, and, of course, the machine type. More importantly, validation also unearths possible issues, allowing us be proactive. This removes most elements of surprise and reduces the time between concept and commercialization even more.



Wheelabrator's Application Validation Center

A Case Study: The Challenge

One such opportunity arose when a prospect contacted Wheelabrator seeking suggestions on strengthening the welded seam along the circumference of a fabricated automotive wheel rim. (The company name is being withheld for reasons of non-disclosure commitments.) Let's follow the process from the point the customer came to Wheelabrator until the time a process specification was developed.

The prospect, a well-known name in the automotive wheel industry, had tangible expectations on weld and ultimately the wheel life. They had not carried out tests to determine the suitability of peening or its ability to enhance the life of the welds stitched along the circumference of their fabricated truck wheel. Here was every peening equipment designer's dream—to develop a peening specification and process for a brand new application!

As in all automotive applications, production volumes were quite large and required reduced cycle times or multiple machines. In addition, this was a new process and there was limited space at their facility to house it.

The manufacturer wanted to produce one wheel every 4.5 seconds and within the aforementioned space constraint. Since they were pioneering this process, they did not want to disclose details about the quantifiable life values expected after shot peening. Their final expectation was a peened product that enhanced weld life and a certified peening process that could be standardized and incorporated into their manufacturing process.

Finding the Solution

Our first task was to blast test sample wheels at our Application Validation center. The center's staff devised a test fixture that was able to spin the wheel in the vertical orientation and expose it to a vertically mounted blast wheel. The blast wheel was driven by a 15 HP motor with an inverter to vary the wheel speed. The rotational speed of the test fixture and the fabricated wheel could also be varied.

The team pooled their collective experience to determine intensity ranges for similar parts that were tested in the past. We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gave the customer a test plan that described all test parameters except the intensity. The intention was for the customer to test the peened samples through x-ray diffraction or other means and choose the set of parameters that gave them the most desirable results. Accordingly, Wheelabrator test peened the wheels to three different intensity ranges: 0.009 to 0.011 A, 0.011 A to 0.015 A and 0.015 A to 0.017 A. These intensity ranges were achieved using two different shot sizes. The customer could also see the difference in coverage achieved from the two shot sizes.

After extensive testing at their end, our customer found the middle range of intensity best suited for their requirement. Given that the welds were not very wide, greater coverage achieved with smaller size shot (S 170 in this case) and the associated compressive stress outweighed a higher intensity value obtained with larger size shot at reduced coverage. Coverage could been increased with longer exposure time. However, we were also working within the constraints of a defined cycle time. The only parameter we could vary was the media flow rate using a higher horsepower motor. We have learned from many shot peening exercises that more media is not necessarily beneficial in peening.

Translating Test Data Into Machine Design

Our peening tests provided a saturation time of 24 seconds per wheel in our test rig. After careful consideration of the space constraints at the work site and customer preferences for loading and unloading, the Wheelabrator concept team determined a multi-table design as the best solution for our customer. Our customer was well-versed with robotic loading and unloading systems and decided to employ the same for this process.

Based on production volumes, Wheelabrator proposed a solution of two identical machines. Each machine was fitted with eight satellite tables mounted on a main indexing rotary table. Information on cycle time from our tests allowed us a specific idle time that we used for indexing. This also helped us determine the quantity of satellite tables on the main table.

Blasting in each machine was carried out by two horizontally mounted blast wheels spinning at 3600 RPM (programmed to run at a lower speed), and powered by a 15 HP motor each. The operating sequence is as follows:

- Two identical robots are positioned in front of each machine.
- One of the robots picks up two wheels from a conveyor with specially designed grippers and loads them on two exposed satellite tables.
- The main table indexes to carry the new parts into the machine and exposes two peened parts to the load/unload area.
- The second robot picks up the two peened parts and transfers them to an outfeed conveyor for downstream operations.

Repeatability and consistency of peening results were paramount to our customer, as it should be in any peening operation. The blast wheels were fitted with variable frequency drives for speed variation and feedback loop to check if the wheel speed was within tolerance. Our customer continues to carry out saturation tests and to plot saturation curves at regular intervals to ensure a repeatable process. The satellite table drive was also controlled by an inverter so that the spinner speed could be varied. Though this flexibility is available, once set, the process doesn't require this parameter to be changed. Media flow was monitored and controlled by two VLP MagnaValves. Media size was monitored and undersized abrasive (smaller than S170) was removed by a 48″ vibratory classifier. Due to flow capacity constraints of the classifier, it continuously classified a percentage of the total flow from the two blast wheels.

The entire mechanical system was sequenced by an Allen-Bradley PLC with a PanelviewPlus TouchScreen HMI. With this interface, the customer continues to obtain process information in real-time. They also monitor machine health and troubleshoot issues using the I/O maps provided in the interface.

Our customer wanted a shot-peening process to strengthen the welded seam on truck rims.

Lessons Learned

Wheelabrator's new process met the customer's end goal of improved weld and wheel life. The intensity range was tested with the developed parameters at Wheelabrator and found satisfactory, however, the intensity results at the job site were at the lower end of the range. After multiple discussions within Wheelabrator and with the customer, we decided to keep the shot size but use the next range of higher hardness. This brought up the intensity values by approximately 0.002″, leaving sufficient margins at both ends of the range.

The Wheelabrator design team also developed an electro-pneumatically powered masking arrangement to protect the inside of the wheel from getting blasted by overspray. The mechanism for this arrangement was mounted on the roof of the cabinet to protect it from damage from the blast media.

We started our discussions with thoughts on the future industry. Wheelabrator believes that the guiding principles for a successful career or market position in the shot peening or blast cleaning industries are going to be helping customers (or your employer) accomplish more in less time, without sacrificing effectiveness. Developing and testing the process shortened the cycle time for both us and our customer. Involving our customer in product and process development increased their confidence in the final product. Elimination of equipment performance risks, assurance of reliable and repeatable results, and innovative problem-solving skills are how Wheelabrator continues to shape the industry of the future.

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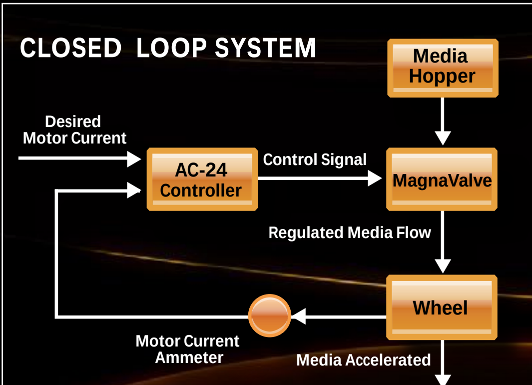

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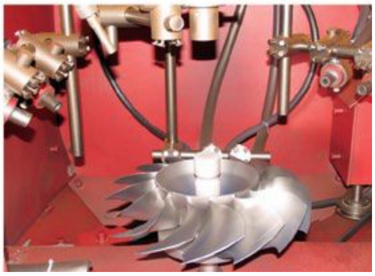

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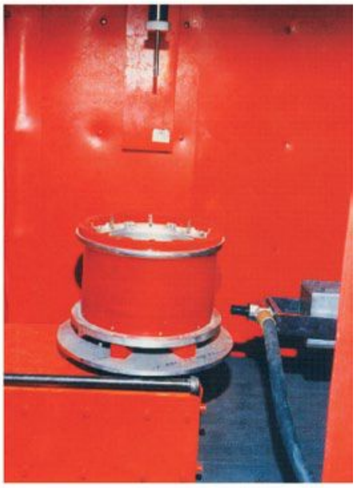

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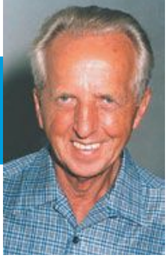

ACADEMIC STUDY

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

Shot Peening Coverage Requirements

INTRODUCTION

Users require that their components should be peened to specified levels of coverage. They also require that the shot stream used has specified characteristics – such as intensity, shot size and type. The term "coverage" is well-understood as being the percentage of the peened surface that has been indented at least once. Testing for coverage is quite independent of testing for intensity and should be determined using specified procedures – such as those described in SAE J2277 "Shot Peening Coverage Determination."

Every experienced shot peener is familiar with the effect of shot peening time on coverage evolution. Fig.1 is very similar to the coverage/amount-of-peening curve published as fig.3 of SAE J443, 1952. The shape of the curve shown is called "exponential" because the coverage value can only approach 100% but never quite reaches it. Coverage is the sum of the contributions made by numerous individual indents. These indents are being created at what is called the "indent rate."

The greater the coverage the greater is the chance that a new indent will overlap a previous indent – or even hit a cluster of previous indents and make no contribution to coverage at all. This is illustrated by fig.2.

In specifying their coverage requirements many customers consider that "more peening is better". Hence we encounter requests such as 200% and 300%. It should be kept in mind, however, that it is not the dents themselves that improve the service performance of peened components. Improvement comes primarily from surface residual compressive stress and also, but to a lesser extent, surface work-hardening. There is a growing realization that maximum compressive residual stress levels and optimum work-hardening generally occur with significantly less than 100% coverage. Hence, in general, "more peening is not better." Carburized components provide an interesting parallel. Optimum fatigue performance generally coincides with the presence of a small percentage of retained austenite in the final, tempered, structure. Myriads of tiny austenite particles act as 'escape routes' for dislocations being piled up that would otherwise initiate fatigue cracks.

One formal definition of coverage is that contained in SAE J2277, 2009:

> *"Coverage is defined as the percentage of a surface that has been indented at least once by the peening media. It is, however, very difficult to obtain accurate measurements of coverage above 98%. "Full coverage" is therefore defined as being at least 98% denting of the surface to be peened. Coverage above "full coverage," when required, is obtained by peening for multiples of the time required for "full coverage."*

This J2277, 2009 definition of "full coverage" is flawed by the inclusion of the words "at least". This, unintentionally, allows any amount of peening above 98% coverage to satisfy the "full coverage" requirement. The flaw is currently being corrected by substituting the word "approximately" for the words "at least."

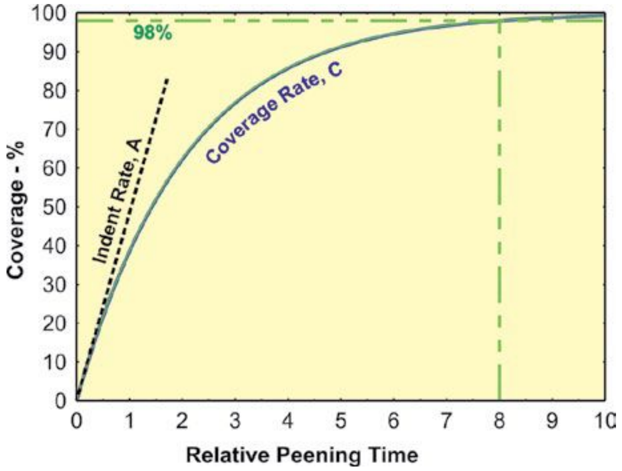

Fig.1. Relationship of Coverage to Peening Time and Indent Rate.

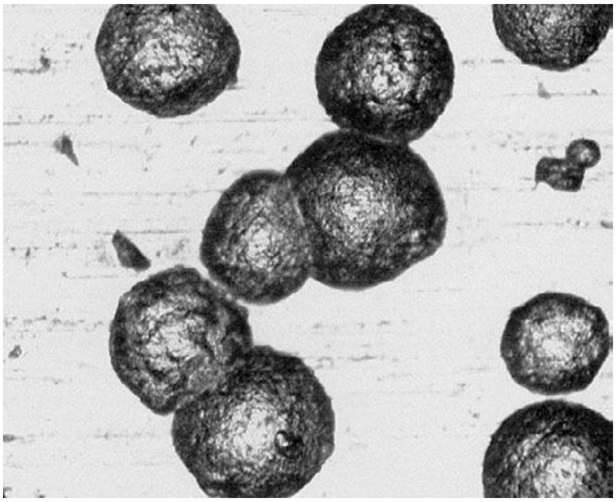

Fig.2 Micrograph of shot peened steel showing overlapping indents.

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Shot peening coverage requirements are probably best specified with reference to "full coverage" – where that corresponds to "approximately 98%". Anything greater than 98% coverage should only be required if there is proof that it does not detract from optimum component performance.

Shot peeners have to adjust the amount of peening applied to components in order to satisfy whatever coverage level has been specified by the customer. A quantitative relationship between coverage and amount of peening has been available for sixty years – described in SAE J443 1952. This relationship together with other useful relationships is presented in this article. No mathematical ability is needed to use these relationships. All that is necessary is the ability make a single coverage measurement and to insert the result into an appropriate computer program.

FULL COVERAGE

A pictorial approach aiming at 98% coverage is illustrated by fig.3. This approach starts with the assumption that coverage is measured after one pass (or equivalent time unit). If this is found to reach 98% then the objective has been reached. If, however, it is less than 98% then further passes (or extra time) would be needed. Fig.3 shows how many passes in total

Passes to reach 'Full Coverage'	Measured 1 Pass Coverage
1 PASS	98%+
2 PASSES	<98% >86%
3 PASSES	<86% >73%
4 PASSES	<73% >62%
5 PASSES	<62% >54%
6 PASSES	<54% >48%
7 PASSES	<48% >43%
8 PASSES	<43% >39%
9 PASSES	<39% >35%
10 PASSES	<35% >32%

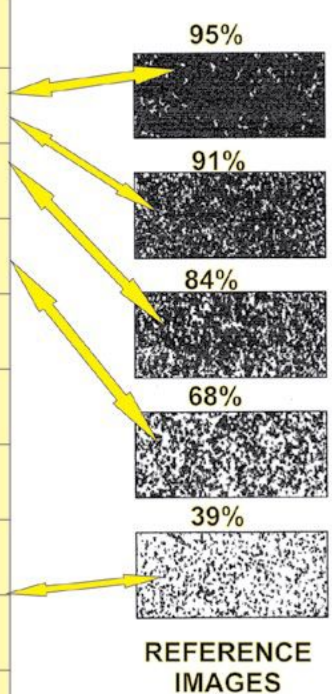

Fig.3. Predicting passes needed for 98% coverage using Reference Images.

would be needed to achieve 98%. This includes any first-pass coverage of over 32% (less than 32% would correspond to an uneconomical situation).

If, for example, a coverage of 58% was measured after one pass then a total of five passes would be needed. The 'green-to-red' shading of the passes to reach 'full coverage' is indicative. Hence, if the one pass coverage was, say, 54.5% then it would be in a red shaded area. That indicates that caution must be taken in assuming that a total of only five passes is needed - because complete reliance is being placed on the accuracy of one measurement. Conversely if the one pass coverage had been, say, 61% then there would be a 'green' indication that a total of only five passes could be relied on.

The arrows from the reference images in fig.3 show the corresponding points on the table of pass requirements.

COVERAGE/AMOUNT OF PEENING RELATIONSHIPS

A quantitative relationship between coverage and amount of peening is essential for the proper control of coverage. Such a relationship has to solve the problem of the diminishing contributions of impacts to coverage as peening progresses. This problem was solved as early as 1939 by M. Avrami.

1) Avrami Equation

Avrami's simplest equation (one of several that he produced) is commonly employed to relate coverage to the amount of peening. This fundamental relationship can be expressed as:

$$\mathbf{C_t \% = 100[1 - exp(-A*t)]} \qquad (1)$$

where C_t % is the coverage after a time **t** and **A** is the indent rate.

A is the ratio of **total area of indents to targeted area produced in 1 unit of peening time. t** is the number of peening time units used. Imagine, for example, that 500mm^2 of indents are applied in one pass (t=1) to each 1000mm^2 of component surface. The indent rate, **A**, is then 0.5 per pass. With two passes the time, **t**, becomes equal to 2.

If **= 100*(1 – EXP(-0.5))** is typed into the formula bar of an Excel spreadsheet for a pre-selected cell, then it would give the value of 39.3. That is Avrami's equation at work, allowing for the overlapping that must have occurred. Substituting 1.0 for the 0.5 in the formula bar would give the answer 63.2. This example shows that a coverage of 39.3% would have resulted from applying an indent rate of 0.5 for 1 pass and 63.2% would have resulted from applying 2 passes.

2) Coverage based on one measured value of coverage

Equation (1) is mainly of academic interest - since the indent rate, **A**, is rarely measured during practical shot peening. What is commonly measured is the coverage that was actually achieved in 1 unit of 'time' e.g. 1 pass. Equation (1) can be written as:

$$\mathbf{A = -ln[(100 - C_1)/100]} \qquad (2)$$

where **ln** stands for 'natural logarithm' and C_1 is the coverage % measured after 1 pass.


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Using the previous example, typing = **-LN((100 – 39.2)/100)** into the formula bar of an Excel spreadsheet would yield **0.50** as the value for **A**. Substituting 63.2 for the 39.3 would yield **1.0** for the value of **A**. This simply shows that the same values arise when working backwards.

The great value of equation (2) is that it can be used to determine the indent rate, **A**, that has been applied when a coverage of C_1 has been measured. This value of **A** can then be substituted into equation (1) – thus enabling prediction of the coverage that would arise for any given number of passes (or time units). This two-stage mathematical operation is built into the author's Excel-based "Coverage Predictor Program."

When SAE J443 was published in 1952, universal access to computers was not available. A modified form of equation (1) was included so that only a single-stage mathematical operation was needed to predict multi-pass coverage based on a single measurement – C_1. Even that operation could be avoided by using the included "nomograph." This was a straight-line relationship achieved by using "log-log" paper. The modified form of equation (1) used was that:

$$\mathbf{C_2 = 1 - (1 - C_1)^n} \qquad (3)$$

where C_1 = % coverage (decimal) after 1 pass and C_2 = % coverage (decimal) after **n** passes.

Equation (4) is simply equation (3) written in non-decimal format and with n replacing the **2**.

$$\mathbf{C_n = 100(1 - ((100 - C_1)/100)^n} \qquad (4)$$

where C_1 = % coverage after 1 pass and C_n = % coverage after **n** passes.

Substituting the value of 39.3% for C_1 (obtained earlier) and **n = 2** into equation (4) gives a predicted coverage (for 2 passes) of 63.2%. That is precisely the same value as was predicted using the original Avrami equation. This is not unexpected because **equations (1) and (4) are the same** – they are just presented differently. They will always give the same predicted answers. The proof of this equivalence of the 1939 Avrami and 1952 J443 equations is only of academic interest. A mathematical proof of the equivalence follows because the statement must withstand academic scrutiny.

Proof of Equivalence of Avrami and J443 equations

This proof traces the conversion of the Avrami equation into the J443 equation.

Avrami $\quad C_n = 100(1 - \exp(-A*n)) \qquad (a)$

But $\exp(-A*n) = (\exp(-A))^n$ *so that (a) can be written as:*

$$C_n = 100(1 - (\exp(-A)^n) \qquad (b)$$

When n = 1 equation (b) becomes:

$$C_1 = 100(1 - \exp(-A)) \text{ so that}$$

$$\exp(-A) = (100 - C_1)/100 \text{ so that}$$

$$\exp(-A)^n = ((100 - C_1)/100)^n = \exp(-A*n)$$

Substituting $((100 - C_1)/100)^n$ *for* $\exp(-A*n)$ *in equation (a) gives:*

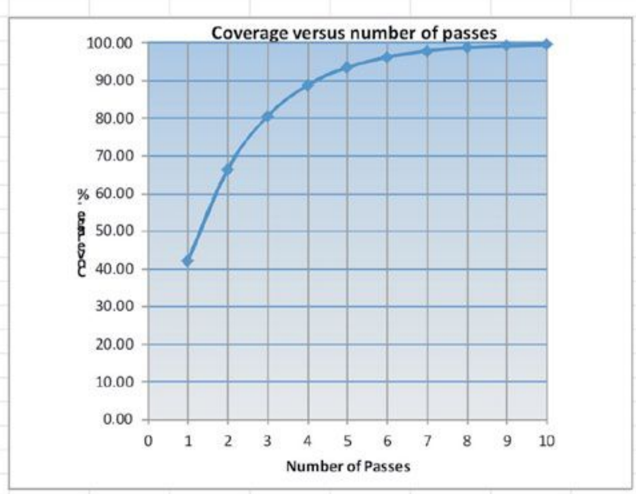
J443 $\quad C_n = 100(1 - ((100 - C_1)/100)^n) \qquad (c)$

Equation (c) is exactly the same as the non-decimal form of the J443 equation given as equation (4). ***Q.E.D.***

COVERAGE PREDICTION PROGRAM AND ITS APPLICATION

A simple Coverage Prediction program has been produced and is available free from www.shotpeener.com. Fig.4 shows a program example with the first data point inserted, as instructed. Numerical predicted coverage values are given – which saves having to read them from the graph. The program calculates the A-value by using equation (2) and then predicts coverages using equation (1).

No. of Passes	Coverage - %
1	42.00
2	66.36
3	80.49
4	88.68
5	93.44
6	96.19
7	97.79
8	98.72
9	99.26
10	99.57
A - value	
0.545	



INSTRUCTIONS: Enter measured value of coverage into Cell B2

Fig.4. Example showing application of Coverage Prediction program.

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As an example of coverage prediction accuracy, consider the following real situation. A set of measured coverages (not made by the author) are given in Table 1.

Table 1. Measured Coverages using S230 shot.

No. of Passes	Measured Coverage - %
1	42
2	68
4	84
6	95
8	98.5

Fig.5 shows the data points of Table 1 plotted together with (a) a coverage prediction curve using the first data point as C_1 in equation (2) and (b) an Avrami curve best-fitting to the set of data points. It can be seen from fig.5 that the predicted and actual curves are very close to one another. The actual data points do not lie exactly on the best-fitting curve – as would be expected.

It is important to note that the equations described previously rely on the value of coverage actually measured after a known 'time'.

PRE-PLANNING VERSUS POST-MORTEM

Pre-Planning

The previous section showed how coverage can be predicted by using pre-planning. With pre-planning, coverage is measured for one unit of applied peening time (such as that for a single pass) This can then be used to calculate the coverage that will be achieved after multiples of that time unit.

Post-Mortem

An alternative to pre-planning is to use a post-mortem approach (for want of a better phrase). With this approach the shot peener assumes beforehand that the required coverage will be achieved in a known number of time units. For example: it was assumed that 98% coverage would be achieved with 6 passes. On examination it was found that the coverage was only 96%. The obvious question then is "How many extra passes would be needed to achieve 98% coverage?"

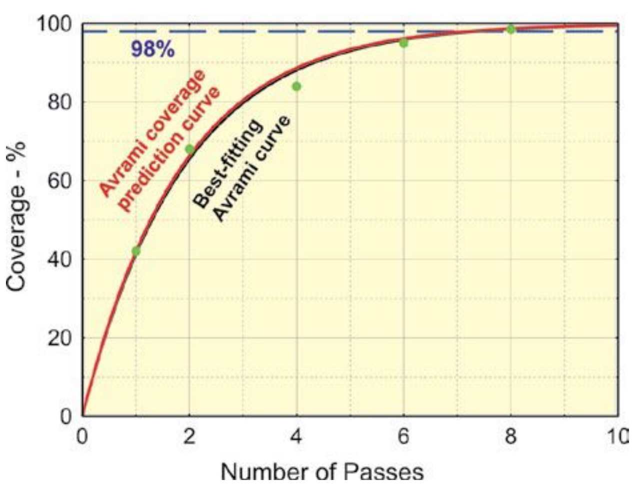


Fig.5. Avrami coverage prediction and 'best-fitting' curves for data given in Table 1.

The following is a description of how 'post-mortem' calculations can be made. These calculations can be carried out using a modified version of the Coverage Predictor program – without needing to understand the procedure that follows.

Equation (2) can be modified to allow for the measured coverage being $\mathbf{C_n}$ occurring after **n** passes:

$$\mathbf{A = -ln[(100 - C_n)/100]/n} \qquad (5)$$

The value derived using equation (5) is then substituted into equation (1) using t = 1 to derive $\mathbf{C_1}$. This derived value of $\mathbf{C_1}$ for the 'required value' is then used in the Coverage Predictor program. As an example: if coverage after 6 passes was measured to be 96% then substitution in (5) would give that **A = 0.536**. Substituting that value into equation (1) with **t = 1** would give that $\mathbf{C_1}$ **= 42%**. Substituting $\mathbf{C_1}$ **= 42%** into the Coverage Predictor program would produce the results shown as fig.6 on page 32. From that it is predicted that **8 passes** would give 98% coverage – rather than the 6 passes which gave 96%. Fig.6 shows Sheet 2 of the modified Coverage Predictor program that has carried out the calculations automatically.

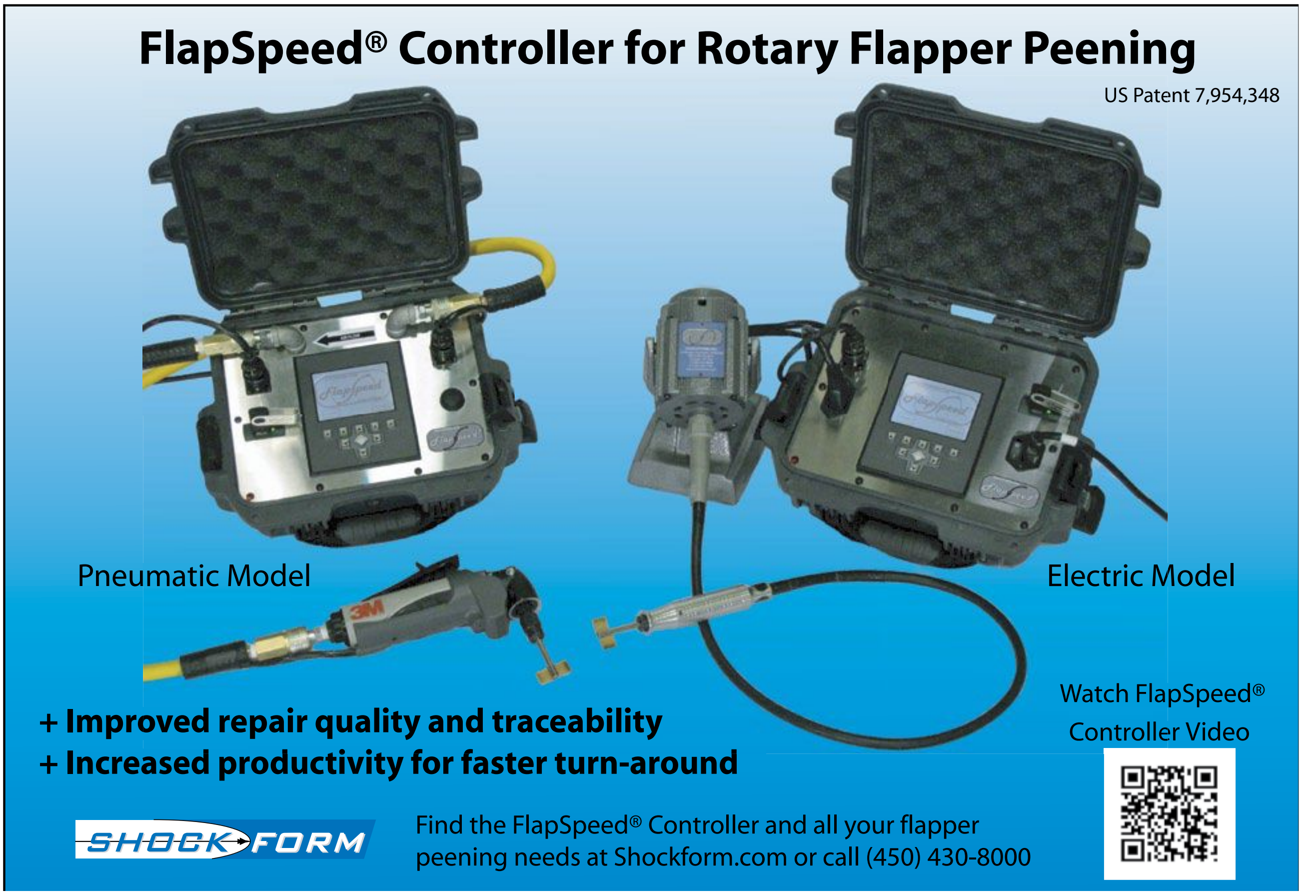
EFFECT OF INDENT RATE ON COVERAGE

Customers generally specify the shot type and peening intensity that has to be applied to their components. Shot flow rate and applied peening time are then the only coverage control factors available to the shot peener. Doubling the shot flow rate would double the indent rate - <u>but only if the peening intensity was also maintained</u>. Fig.7 (page 32) illustrates the effect of different indent rates on coverage evolution. The range of indent rates shown is not enormous – simply ten to one.

It follows from fig.7 that an indent rate of less than 0.4 is going to be impractical for most purposes - more than ten passes being needed to achieve 98% coverage. An enlightened customer requiring a minimum of 85% coverage could be accommodated with an indent rate of only 0.2 - provided that at least 10 passes were applied. A second important conclusion from fig.7 is that shot flow control is very important when it comes to controlling coverages. For example, if an indent rate achieved 98% coverage in 4 passes then a 10% drop in flow rate would mean that an extra pass would be required.

ASSESSMENT OF COVERAGE

Assessment of the coverage after 1 pass is critical for pre-planned coverage control. Assessment of the fully-peened



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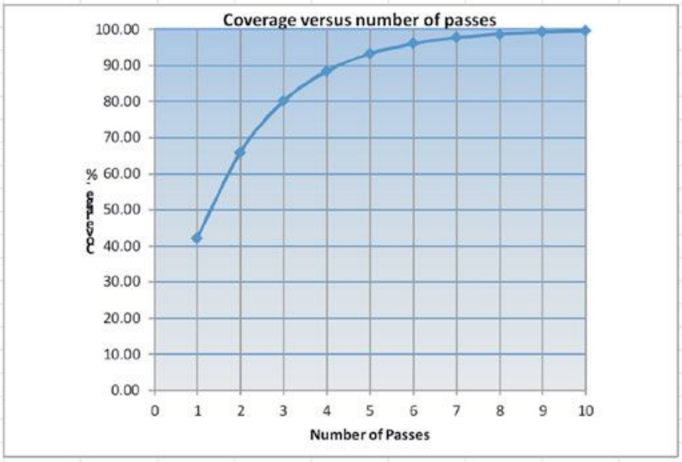
No. of Passes	Coverage - %
1	42.00
2	65.80
3	80.00
4	88.30
5	93.16
6	96.00
7	97.66
8	98.63
9	99.20
10	99.53
A - value	
0.536	



No. of Passes	Measured Coverage - %
6	96

Enter No. of Passes & Measured Coverage in Yellow Boxes

Fig.6. Coverage Prediction after one coverage measurement at six passes.

component is also critical if the customer's requirements are to be satisfied. The more accurate the coverage assessment the easier it will be to achieve both objectives. A basic premise is that coverage assessment is most accurate when the coverage is 50% - when there are equal amounts of peened and unpeened areas.

There are a number of practical methods of coverage assessment. The simplest combination is probably that of an operator using a 10x magnifying glass and mentally comparing the images with those stored in a human memory. This should not be under-rated as a method. Experienced operators can accurately assess coverage – certainly to better than 5% at low coverages and to better than 2% at high coverages.

Image capture is vital if a record of the coverage is to be retained. There are many applicable devices, most of which

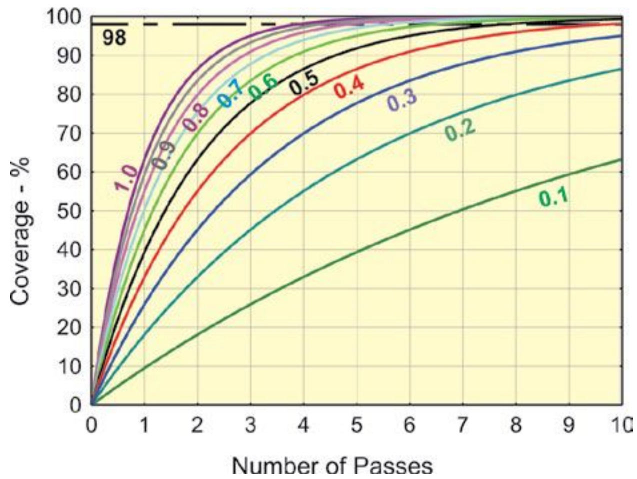


Fig.7. Effect of Indent Rate on Coverage evolution.

now involve recording a digital image of the peened surface. The surface may be directly photographed using the zoom facility of a digital camera or may involve a digital camera/microscope combination. It follows that the better the optics the better will be the quality of the recorded image.

All coverage assessment methods require some form of image reference. Reference images are included in fig.3 but a set of digitized images is of much better practicality. Digitized reference images can be computer-manipulated to match the lighting conditions and surface reflection behavior of shot peened components.

A useful reference set is that shown as fig.8 (page 34). This set of computer-generated images was kindly supplied by Dale Lombardo of GE Energy. The supplied images are shown (in grayscale) as the left column and after computerized color-inversion (white to black) on the right.

DISCUSSION

Satisfying customers' coverage and peening intensity requirements are the two prime objectives for shot peeners. The procedures described in this article allow optimization of coverage satisfaction. The equations presented are robust, well-tried, and agree closely with measured coverage evolution.

The controlling factors for coverage attainment are indent rate and peening time. Indent rates are easily deduced and employed in coverage prediction. Deduced indent rates are surprisingly constant - provided that the shot stream itself remains constant. Changing the flow rate in order to change the indent rate has attendant problems: (1) media flow rate can affect air blast media velocity and (2) excessively high flow rates might result in congestion at the surface - rebounding media interfering with incoming media. It follows that if the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flow rate is changed then a new coverage measurement has to be made.

Predicted coverages using time multiples are accurate if one coverage measurement is made when approximately 40-60% coverage has been applied. Confirmation of achieving a high level of coverage is, however, difficult. Reference images are very useful, particularly when attempting to assess high coverage levels.

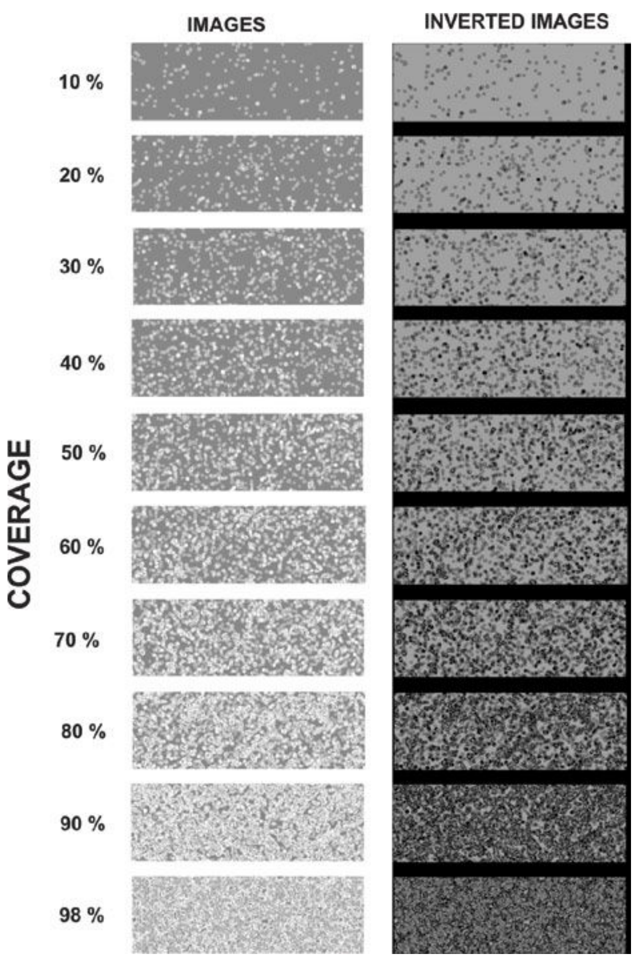

Fig.8. Computer-generated reference images. Courtesy of Dale Lombardo, GE Energy.

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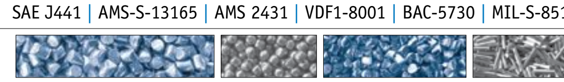

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How to Descale 14 Tons of Drawn Steel Bars in One Hour

DRAWN STEEL, also known as bright steel, is often used in the production of injection parts for diesel engines and must meet strict quality standards. A key stage in the manufacturing of drawn bright steel is the blast cleaning of the raw material prior to the drawing process. Recently, Rösler developed a continuous shot blast system for Saar-Blankstahl GmbH that allows the fully automatic blast cleaning of steel bars with diameters/cross-sectional dimensions of 24 up to 80 mm (approximately 1.0 – 3.2 inches). This system not only produces excellent descaling results but it also permits processing speeds of up to 60 meters (197 feet) per minute.

Blast Cleaning – A Critical Step in the Overall Manufacturing Process

Prior to being drawn into steel bars with standard round, square and hexagonal profile as well as steel bars with special profiles, the rolled steel must be blast cleaned to remove scale and rust from its surface. Explains Günther Dorscheid, plant manager at Saar-Blankstahl: "Blast cleaning is highly critical for meeting the specific customer requirements for an absolutely homogeneous surface for two reasons: Residual scale on the steel can damage the drawing die which causes scratch marks on the drawn steel products, and scale embedded in the drawn steel can damage the tools during the subsequent machining process. For these reasons, after the blast cleaning process, the surface of the rolled steel must have a degree of cleanliness of SA 2,5 – SA 3." This was a key requirement for the replacement of the old shot blast machine with a new blast cleaning system in Saar-Blankstahl GmbH's Burbach plant. In addition, the customer specifications called for a high parts throughput, high equipment availability, ease of maintenance and a highly efficient dust collection system. Another very important requirement was the integration of the new shot blast system into the existing manufacturing line. As the plant manager points out: "Especially the latter point was a real challenge, because the bridge crane in this section of the building has a relatively low height."

In this continuous shot blast machine with three blast chambers, steel bars with round, square and hexagonal profiles and diameters/cross-sectional dimensions from 24 to 80 mm (1.0 to 3.2 inches) can be processed at a speed from 12 to 60 m (39 to 197 feet) per minute.

A Convincing Custom-Engineered Concept

Mr. Dorscheid continues: "We only found out about Rösler after our negotiations with other equipment manufacturers were already underway. We visited the plant in Untermerzbach and were quite impressed by what we saw." Even though Rösler at this time had not yet built a comparable shot blast system, the customer placed its order with the company from Untermerzbach. Key factors for selecting Rösler were the convincing equipment concept and the willingness of Rösler to adapt its continuous shot blast system REDL 6-30/100 to the local space conditions at Saar- Blankstahl in Burbach. The excellent experience of Günther Dorscheid's former colleagues with a pipe blaster from Rösler also helped.

Designed for High Capacity

The REDL 6-30/100 allows the blast cleaning of steel bars with round, square and hexagonal profile and cross sectional dimensions from 24 to 80 mm (approximately 1.0 to 3.2 inches). The transport of the steel bars takes place on transport rollers made from annealed tool steel. In the case of "light

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13251 George Weber Drive, Rogers, Minnesota USA 55374 weight" parts, special pressure rollers prevent the bars from slipping. The processing speed can be individually adjusted to the parts being processed within a range of 12 – 60 m (39 – 197 feet) per minute. This ensures that even in the case of steel bars with extreme rust and scale on their surface (rust grade "C") a cleanliness of SA 3 can be achieved without difficulty.

The Rösler blast machine is equipped with six high-performance blast turbines, type EVO 38, with an installed drive power of 30 kW each and a blast media throughput of up to 430 kg (946 lbs) per minute. The critical parts of these twin disk turbines are made from wear resistant materials like hardened tool steel and manganese steel. The housing is made from interlocking laser cut parts resulting in a highly robust design with a high life expectation. The slide-in, centrifugally locking throwing blades eliminate the need for fast wearing screws and springs. Moreover, the EVO turbines allow a simple and quick replacement of the throwing blades.

States the plant manager: "The new shot blast system is so productive that it has practically doubled our shot blast capacity with the blast cleaning process now being significantly faster than the drawing operation. We can now place the blast cleaned steel bars into a special buffer stock which allows us to turn off the shot blast machine for several hours per day. This not only helps to reduce our energy costs but also our requirements for wear parts and blast media. Of course, we now also have a welcome capacity reserve in our shot blast operation."

Optimum Protection Against Wear

Two turbines offset by 60° are strategically placed in each of the three blast chambers in a manner that allows the blast media always hitting the raw steel bars at an angle of 90°. The equipment concept with entry, center and exit blast chamber offers various advantages. For example, it prevents the turbines from blasting into each other which could cause serious damage. At the same time, this partitioning allows the placement of the transport rollers for the steel bars in areas which are not directly exposed to the blast stream, thus significantly reducing their wear rate. Those sections of the three blast chambers directly exposed to the blast stream are lined with easy to replace wear plates made from manganese steel, respectively, from hardened tool steel. The transport rollers are also made from hardened tool steel. The pressure rollers are made from a Vulkolan elastomer that helps prevent damage on the parts from trapped blast media.

Efficient Cleaning of the Blast Media and the Exhaust Air

To meet the height requirement for the shot blast machine of only 4,600 mm (181 inches), the REDL 6-30/100 was designed with a specially low profile. For this purpose the blast media classification system was not placed, as it is usually done, on top of the machine, but beside it. For this reason, the machine is equipped with a "split" elevator system consisting of two bucket elevators. A cross screw conveyor transfers the contaminated blast media from the blast chamber to the first bucket elevator which transports the blast media up to the air wash media classification system. The air stream flowing through the media curtain removes contaminants like broken down media and dust. Heavy particles are collected in a special bin, while dust fines are transported to a dust collector. The cleaned blast media is collected in a storage hopper placed directly below the air wash separator. From there the second bucket elevator transports the media to an intermediate hopper placed above the turbines. This arrangement allows a continuous, uninterrupted flow of the blast media to the turbines.

The contaminated exhaust air from the blast chamber is first cleaned in a cartridge dust collector. Subsequently, the clean air is passing through a fine filter for further reduction of the residual dust load. In winter, the clean air from the dust collector can be guided back into the building, contributing to overall reduced energy consumption.

Integration of the System Controls Already During the Pre-Commissioning Phase

The Rösler shot blast system is integrated into a complete manufacturing line. This required not only a quick exchange of the old with the new shot blast machine controls but also their integration into the higher level line controls. In this respect a big benefit for Saar-Blankstahl was the fact Rösler completely sets up its equipment in Untermerzbach prior to shipment and conducts extensive trial runs. Günther Dorscheid explains: "Other equipment manufacturers would have delivered single components, installed them at our plant in Burbach and tested the equipment for the first time on site. At Rösler we had the opportunity to test a fully functional shot blast system during the pre-commissioning phase in Untermerzbach. This allowed us to jointly test and optimize the integration of the controls with our own control engineers like, for example, the operating concept, the monitoring and tracing of product batches, etc. This helped us replacing the old shot blast machine with the new one within a time period of only four weeks."

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THE P-3 ORION turboprop aircraft has been in active military service for almost 50 years. These planes were developed to operate in the harshest environments and are used for surveillance, combat, cargo and research duties. The P-3 has seen action in Vietnam, Iraq, Afghanistan and Somalia. With a new focus on cost savings, the U.S. military has begun extending the required service life of its airborne fleet. By developing new technologies and maintenance methods, they hope to increase the lifespan of critical planes, such as the P-3, by 20 years or more. Until viable replacements can be developed, each year that a model can see continuous service saves millions of tax dollars.

The P-3 is commonly used in marine environments where it is exposed to corrosion pitting and stress corrosion cracking (SCC) damage that can initiate fatigue failures. The aluminum propeller bore is vulnerable to corrosion, and any cracking can quickly propagate due to high-cycle fatigue during the basic operation of the aircraft. Safe operation requires a rigorous inspection and repair cycle. The previous maintenance practice called for heavy shot peening, followed by reaming to restore the bore finish and re-machining operations to return the proper bore geometry for replacement of a bushing in the tapered section. The P-3 propellers were originally designed for unlimited service life. However, the loss of material during machining required the propellers to be scrapped after just three maintenance cycles.

To offset costs and viably extend the life of the P-3, NAVAIR, the Navy's aviation branch, began looking at other alternatives to shot peening that would reduce the scrap rate of propellers. They chose Low Plasticity Burnishing (LPB®). Developed by Lambda Technologies in Cincinnati, LPB induces a very deep, stable layer of compressive residual stress in the surface of a component. This layer of protection makes the piece dramatically more resistant to damage and can exponentially increase its fatigue life. The process works by rolling a high-hardness ball across the surface of the work piece to create beneficial compression. The ball is supported by a constant volume flow of fluid, preventing any chance of dragging or damaging the component. It leaves a mirror-like surface finish that facilitates inspection and doesn't require additional machining. Parts can be treated during manufacturing or after they have been in service and no alteration of the component's material or design is required.

LPB processing is performed using basic CNC machines or robots, allowing for quick and easy integration into shop processes. Pacific Propeller International (PPI) in Kent, Washington is now performing maintenance on the P-3 propeller bore for NAVAIR using a robotic LPB system. Computer control also guarantees repeatability and process regulation. The closed-loop LPB pressure control system adjusts the burnishing force in real time with precision exceeding Six Sigma quality requirements. Each part is tracked by serial number and SPC information is immediately available to quality control teams. Given the added benefits, PPI was provided with a new way forward for protecting the P-3 from corrosion damage.

"We are very excited to be working with Lambda, and look forward to the future," says Mike Johnson, General Manager of PPI. "Innovative solutions offered by Lambda will help us provide new levels of service to our customers."

The smooth surface finish left by LPB allowed PPI to eliminate the reaming and machining steps. This eliminates the need to scrap the part after three maintenance cycles and indefinitely extends its service life. At $35,000 per propeller, millions can be saved in cost avoidance after just a few years of implementation.

The new LPB method didn't just replace the shot peening process. The compressive layer was deeper and more uniform with LPB. In aluminum applications, like the P-3 propeller bore, Lambda is able to design a protective compressive layer that is deeper than the deepest corrosion pits. Because the material is held in compression to a depth greater than any pits can reach, crack propagation from pits is eliminated. The fatigue life of the propeller bore is dramatically extended as the process also mitigates cracking from stress corrosion cracking and high-cycle fatigue. The speed of processing was also greatly increased, helping to ensure that the aircraft is available when needed. Performing the operation on just one machine also lowered the equipment footprint on the shop floor.

Lambda and NAVAIR took a novel approach to replacing shot peening with LPB by deciding to process the bore robotically. Complete turnkey robotic systems were developed by Lambda and installed at the PPI facility, along with two others at Cherry Point Marine Depot and Warner Robbins Air Force Base. These three systems currently service the entire P-3 fleet. The CNC programmable 6-axis robots combine control and flexibility in ways that more traditional setups can't match.

"The main benefits of robotic processing are control and repeatability. This system is completely closed-loop controlled. That allows us to verify absolutely that we've achieved what we set out to do, and using CNC robots allows us to do it exactly the same way every time," says John Cassidy, Project Quality Engineer at Lambda.

The P-3 propeller bore can be problematic to process. A six-axis robot fitted with Lambda's tooling is easily adapted to difficult or odd geometries, and the inside of a propeller bore posed no problem. Robotic systems are also not limited to one application. With a simple CNC code and tool change, they can very quickly be treating a component with an entirely different design.

The systems Lambda installed are a true "push-button" technology. The common interface makes the process easy to use and doesn't require extensive training on exotic machinery. Operators only need to load the part to be processed and start the procedure. There are no environmental or safety hazards, and LPB offers the logistical advantage that part need not be moved to a remote facility or different section of the processing plant. In some maintenance situations, LPB processing can even be performed in-situ, without removing the piece from service. LPB treatment is usually done in a matter of minutes, and systems can be developed to process multiple parts without the need for operator intervention.

The P-3 is not going away. Thanks to a determination to find new answers to old problems, this versatile and robust aircraft will continue to serve as long as it is needed. However, the benefit is not limited to just military aircraft, and PPI plans to expand its operation to offer LPB treatment to more of its customers.

Robotic Processing of the P-3 Propeller Bore

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Shot Peening Meets the Pinewood Derby

A Brief Investigation into the Effects of Shot Peening on Sliding Friction Between Metal and Plastic

ACCORDING TO *READER'S DIGEST*, The Pinewood Derby is an essential rite of Spring. For those not familiar, the Pinewood Derby is an event run by the Boy Scouts of America (BSA), typically at the Cub Scout level. Like other Cub Scout packs nationwide, Pack 46 in Morrisville, Pennsylvania has its derby every April at a local church.

In the derby, small model cars made from pine roll down a ramp to a horizontal racing surface. The maximum footprint of the cars is limited to seven inches long by two and three-quarter inches wide. Weight is limited to five ounces. The wheels must be BSA-approved wheels and are all of the same hardness. The plastic wheels ride on a metal axle. Sanding and polishing the axles prior to installation is encouraged.

The potential energy from the height at the top of the ramp is converted to kinetic energy at the finish line. Friction and drag steal this kinetic energy throughout the race. So it is no surprise that children (and more than a few parents) spend their time reducing friction and drag as much as possible.

Shot peening, the process of bombarding a surface with spherical media, has long been known to prevent failure due to high cycle fatigue. Other benefits include enhanced appearance, surface work hardening and resistance to stress corrosion cracking. It is also known to reduce sliding friction. Changing the smooth surface to a dimpled surface reduces the amount of surface area in contact with whatever is sliding over it. Using spherical media gives rounded peaks to the peaks and valleys, so the metal axle doesn't dig into the plastic wheel. The question was: could shot peening reduce the sliding friction enough to make a difference in a Pinewood Derby race?

David Massey's son's car is typical of a Pinewood Derby car: it's made of pine and is seven-inches long and two and three-quarter inches wide. The big difference is that the axles were shot peened to reduce sliding friction between the metal axle and plastic wheel.

The answer was yes.

In preparation for the derby, my son and I worked with two other father-and-son teams to optimize the Pinewood Derby race car. One of the fathers built a test track in his basement, complete with digital timing. Each team designed experiments to determine the impacts of different variables such as weight distribution, wind resistance, and in our case, axle condition. Not only did the boys learn about physics and the scientific method, but they also got to optimize their cars. While I wasn't able to let my son do any of the actual shot peening due to safety restrictions, we went over what was done and why in exhaustive detail. The following are the results of the shot peening.

Table 1: Course time in seconds

	Untreated	Polished	Polished and Shot Peened	% Improvement
Car A	2.118		2.095	1.09%
Car B		2.125	2.109	0.75%

As noted in the table, when a car's axles were taken from an untreated condition to a polished and shot-peened condition, the car was 0.023 seconds quicker. Each time is an average of three runs on one car, so this experiment is somewhat limited. To isolate whether this was an effect of the shot peening or the polishing, a second test was run with polished axles versus polished and shot peened axles. The car was still 0.016 seconds faster through the course. To give an idea of scale, cars typically ran 2-2.5 seconds. The margin of victory on race day was 0.0025 seconds; roughly one-tenth of the improvement provided by shot peening. By a long way, shot peening provided a great benefit to the Pinewood Derby car.

Most NASCAR teams would pay dearly for a 1% improvement.

So was it enough?

Sadly, no.

We won in our twelve-person den of Bear Cub Scouts by 0.0035 seconds. We lost in the overall pack by 0.0025 seconds to the Cubmaster's son.

David Massey is a Technical Services Manager at Metal Improvement Company (MIC). Photo was taken by Edward Deeny, Quality Manager with Metal Improvement Company. Both work at the MIC facility in Bensalem, Pennsylvania,

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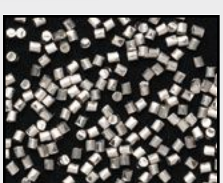

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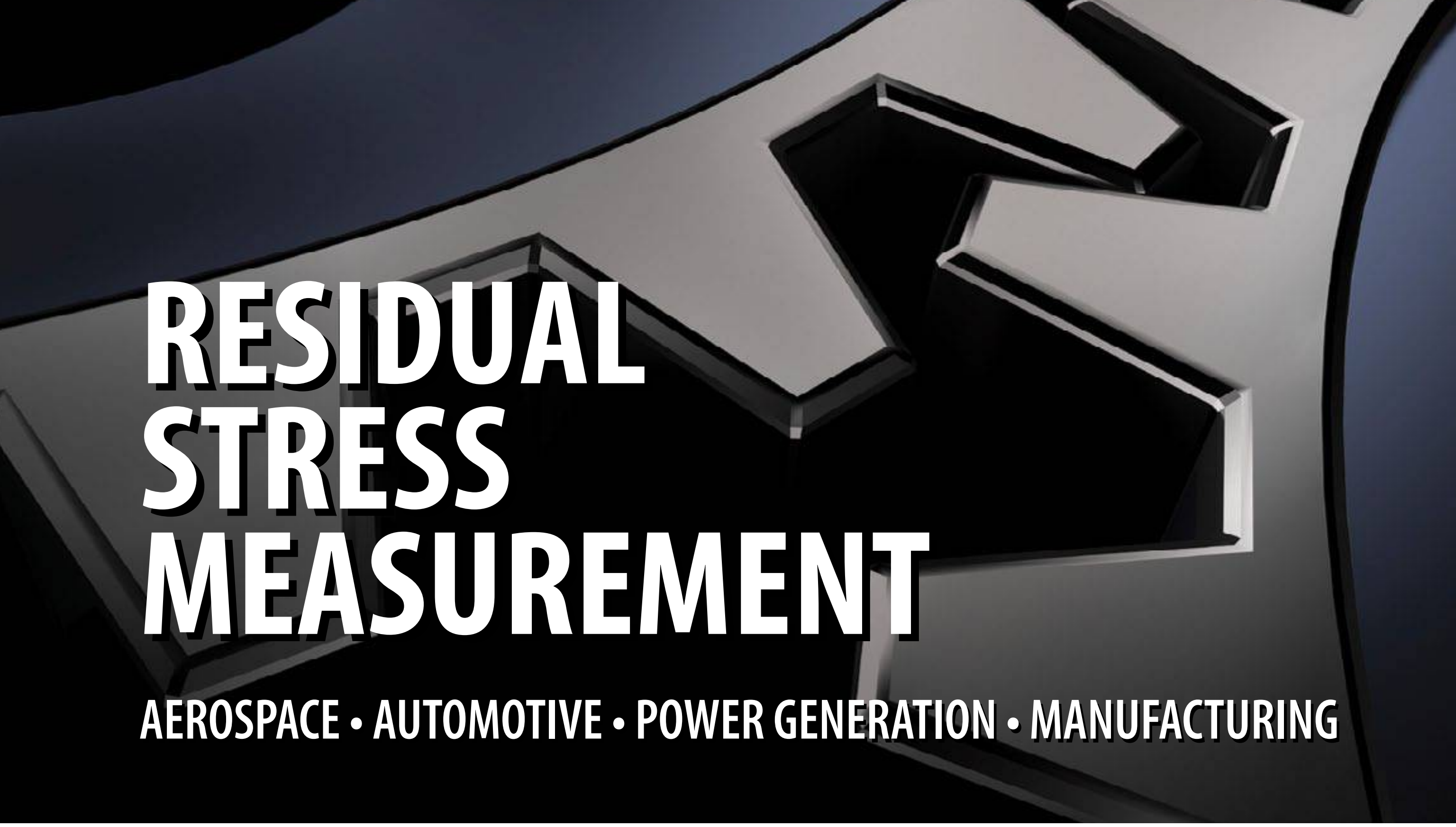

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