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The Shot Peener

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

MIKE WERN
2014 Shot Peener of the Year

PLUS: ACADEMICS & INDUSTRY IN MONTREAL | NANOPEENING® BY WINOA | QUANTIFICATION OF SHOT PEENING INTENSITY RATING

THE SHOT PEENER

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Success Stories

JACK CHAMPAIGNE

MY FIRST SUCCESS STORY is about Martin Lévesque, Professor at the École Polytechnique de Montréal, whose shot peening programs at the university provide valuable peen forming research to local aerospace companies, and whose students receive a great education in a viable, progressive field of manufacturing. Prof. Lévesque has also conducted important shot peening research and is a capable conference organizer—these are the reasons the International Scientific Committee for Shot Peening elected him as the Chairman of the Local Organizing Committee for the Thirteenth International Conference on Shot Peening in 2017. Read about Prof. Lévesque and the synergistic relationship between Polytechnique and the Montreal aerospace community on page 10.

The article from ITAMCO and their contribution to a high school manufacturing training program (page 38) illustrates another successful relationship between education and business. Companies like ITAMCO need skilled machine operators on their high-tech plant floors and high school students need high-paying, satisfying careers when they graduate. The solution is a win-win scenario.

This brings me to yet another success story: Mike Wern. *The Shot Peener* magazine was proud to give him the **2014 Shot Peener of the Year** award because he has done so much to advance shot peening in the U.S. automotive industry. He accomplished this by building such outstanding equipment that shot peening is now a validated and repeatable operation in many U.S. automotive manufacturing facilities. Read more about Mike and Engineered Abrasives on page 6.

Mike received the award at the EI Shot Peening Workshop and Trade Show in Orlando, Florida in October. Unfortunately, this was the first workshop I've missed due to a bug I picked up while traveling home from the German workshop, but I know Mike was truly surprised to receive the award. By the way, these workshops/ seminars/trade shows are another example of a beneficial blend of industry and education.

Best wishes to all for a healthy, happy and prosperous 2015!

The 2014 U.S. Shot Peening Workshop and Trade Show Attendees

THE SHOT PEENER

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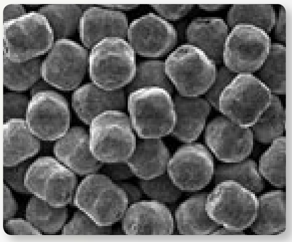

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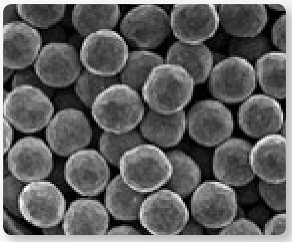

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Building a Solid Reputation

MIKE WERN is a lot like the machines he builds: solid, durable and dependable. It's his approach to manufacturing and the quality of his machines that earned Mike the **2014 Shot Peener of the Year** award from *The Shot Peener* magazine.

Mike is the President and owner of Engineered Abrasives® (EA®), a manufacturer of high-volume shot peening and blast cleaning machines in Alsip, Illinois (a Chicago suburb). Mike's father and grandfather started H&W Sandblast in 1935 and his father and uncle started Engineered Abrasives® in 1968. Mike began working for the company after school when he was eight years old. "Because I was so small, one of my jobs was crawling into Wheelabrator machines and cleaning them out," Mike said. He began working full-time at EA® after he graduated from high school. In 1983, he purchased the business from his family. At that time, EA® employees manufactured hand-blast cabinets and ran a small job shop.

Today, Engineered Abrasives® builds custom and turnkey systems for high-volume applications, including indexing and CNC shot peening machines, deburring machines, grit blasting machines, single cell machines and machines for peening with glass and ceramic bead. The company now has 62,000 sq. ft. of manufacturing space.

In addition, EA® is an ISO/TS 16949, ISO 14001 and Ford Q1 certified job shop, specializing in Ceramic Peening, Glass Bead Peening and Fine Steel® Peening—a process Mike developed for Ford Motor Company and General Motors. The job shop is also a testing facility for the eleven (11) EA® machines that run 24/7. The shot peening technicians test and validate EA® machine components to ensure that an EA® machine meets their customers' demanding production schedules. "No other manufacturer can make that claim," said Mike.

Engineered Abrasives® specializes in their patented rotary index machines for customers in aerospace, appliance, medical, and heavy equipment, but the market EA® dominates is U.S. automotive. According to Mike, "We have built many of the shot peening machines for gears in the U.S.A. automotive industry and are the leading equipment supplier for component OEMs." For example, Mike delivered a machine that cleans the internal oil passages and the entire external surface of V6 aluminum engine blocks at an incredible speed of 90 engine blocks per hour. The rotary index machine, built to customer specifications, is 35 ft. tall and weighs over 20 tons. Engineered Abrasives® recently designed and built a high-volume machine that peens the gear root radius and tooth faces of large rack and pinion gear sets (averaging 500 lb.) for bulldozers, excavators and other heavy-duty equipment.

Engineered Abrasives® machines have done more than build the company's reputation; they have advanced the validity of shot peening in the U.S. automotive industry. "Mike's machines are robust enough that they can work 24/7 and his control panels are so operator friendly that EA® gives shot peening a good reputation as a controllable,

Mike Wern stands by the control panel of an Engineered Abrasives® high-volume index unit with a material handling and robotic system. The machine incorporates EA's patented process to eliminate gear tooth pitting. It will be shipped to a plant in China that builds components for automobiles sold in China.

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"I strongly recommend Shockform Aeronautique for flapper peening equipment. I personally consider them to be the most experienced and knowledgeable team on the Flapper Peening Process. I currently have (2) of the FlapSpeed® units in-house that I use daily on all projects and all types of material with great success. The FlapSpeed® units are very durable and easy to use.

I have developed a great working relationship with their support team. The support that they afford me is far above my expectations. They can also provide certified training for any personnel that would require it."

Harold Camden GKN Aerospace

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repeatable process," said Jack Champaigne, Editor of *The Shot Peener*. Mike's continual innovations in machine design, like the EA® Knowledge System®, enables machine operators to keep pace with increasingly sophisticated shop-floor technology. The EA® Knowledge System® features how-to computer animations on machine operation and maintenance and is available on all EA® machines.

It's almost impossible to run a bad part in an Engineered Abrasives®' machine due to the robustness of the equipment and its monitoring systems.

Heat Treat Engineer, Ford Motor Company

"The U.S. automotive industry is starting to believe in shot peening with air-blast machines and is shot peening more gears than ever," said Mike. He believes the reason is because the new 8- and 10-speed transmissions have more gears. "The need to reduce the weight of the transmission and increase fuel economy is good for shot peening," he added.

Engineered Abrasives® recently hired a distributor in China to expand and support their customer base in the Chinese automobile industry. "I want people to know that our machines are going into Chinese automotive plants that are building cars for the Chinese market. We aren't building machines that will take jobs from the American automotive worker," said Mike. The Chinese company has purchased EA®'s high-volume index units with material handling and robotic systems and their patented process to prevent gear tooth pitting.

EA® is sending a machine to an automotive manufacturer in Poland and the company has become adept at translating their documentation and signage into Chinese, Polish and Spanish (Mexico is another growing market for EA®).

Although Mike works hard to expand his business opportunities, he quietly gives back to the industry—even his competitors. "For years, Mike has sponsored a dinner reception at the annual EI Shot Peening Workshops that is attended by students, instructors and his competitors that exhibit at the event. Many years, Mike was too busy to attend the workshops, so he doesn't do it for the attention. Giving back to others is just the kind of guy he is," said Jack.

Erin Reardon, Mike's daughter, was able to attend the award ceremony at the EI Shot Peening Workshop in Orlando this fall. "Dad built EA® into the business it is today, it wasn't given to him, and it was great to see him get an award for all of those years of hard work." Erin describes her father as a humble man that likes his employees and his vendors and has worked very hard to make the business successful.

While Mike doesn't like to draw attention to himself, *The Shot Peener* magazine is pleased to recognize his work ethic and his shot peening machines that have helped give shot peening the place it deserves as a valuable process in the U.S. automotive industry.

Shot Peener of the Year Award

Since 1992, *The Shot Peener* magazine has given "The Shot Peener of the Year" award to individuals in our industry that have made significant contributions to the advancement of shot peening. We've listed the year of the award, the recipient and their place of employment at the time they received the award.

2014	Mike Wern	Engineered Abrasives®
2013	Scott Hatfield	Medtronic Spinal
2012	Hali Diep	Boeing Research and Technology
2011	James Kernan	U.S. Army Aviation and Missile Research, Development and Engineering Center
2010	Herb Tobben	Clemco Industries
2009	Michelle Bandini	Peen Service
2008	Holger Polanetzki	MTU Aero Engines
2007	Ken l'Anson	Progressive Technologies
2006	Kumar Balan	Wheelabrator Group, Ontario
	Dr. John Cammett	Materials Engineeering Division, Naval Aviation Depot
2005	Marsha Tufft	GE Aircraft Engines
	Helmut Wohlfahrt	Technical University of Braunschweig
2004	Walter Beach	Peening Technologies
	Dr. Katsuji Tosha	Meiji University
2003	Paul Prevey	Lambda Research
	Dr. Niku-Lari	IITT International
2002	David Francis	Metal Improvement Company
	Shaker Meguid	University of Toronto
2001	Dr. David Kirk	Coventry University, U.K.
	Dale Lombardo	GE Aircraft Engines
	Bill Miller	The Boeing Company
2000	Jonathan Clarke	Delta Air Lines
	Lothar Wagner	Technical University of Brandenburg
1999	Andre Levers	British Aerospace Airbus
1998	Wolfgang Linnemann	Kugelstrahlzentrum Aachen
1997	Dr. R. Kopp	Institute Metal Forming of RWTH
1996	Dr. M.C. Sharma	Maulana Azad College of Technology
1995	Dr. Kisuke Iida	Meiji University
1994	Charlie Barrett	Metal Improvement Company
1993	Pete Bailey	GE Aircraft Engines
	Bob Thompson	GE Aircraft Engines
	Jim Whalen	GE Aircraft Engines
1992	Charlie Mason	Menasco Aerospace Ltd.

Academics and Industry Come Together in Montreal

An Interview with Professor Martin Lévesque of the École Polytechnique de Montréal

AT THE CLOSE of the very successful Twelfth International Conference on Shot Peening, the International Scientific Committee for Shot Peening voted to host the 2017 conference in Montreal. Professor Martin Lévesque, Ing. PhD, École Polytechnique de Montréal, is the Chairman of the Local Organizing Committee and Dr. Hongyan Miao, also with École Polytechnique de Montréal, is the Co-Chairman. The event will be held at the Delta Hotel and Polytechnique staff members will oversee the administration of the conference and its website.

Martin Lévesque, Ing, PhD
École Polytechnique de Montréal

The International Scientific Committee for Shot Peening awarded Professor Lévesque the honor of hosting the conference because of his expertise in the shot peening field, especially in the forming of aerospace structures, and his experience in hosting similar events—he organized the successful Mechanics of Time Dependent Materials conference in Montreal in 2014. Professor Lévesque very generously answered our questions regarding the upcoming conference and his work at the École Polytechnique de Montréal. Our discussion will also cover the powerful synergy between the academic community and the aerospace industry in Montreal.

The Shot Peener: Why did you want to host the Thirteenth International Conference on Shot Peening?

Prof. Lévesque: The École Polytechnique de Montréal is the largest engineering school in Québec and the only school in "La Belle Province" (Québec's nickname) to offer a full degree in Aerospace Engineering. Polytechnique has the largest volume of industry-partnered engineering research in Canada, making the university uniquely qualified to appreciate the relationship between academic research and real-life applications. This interconnection is an important component of the shot peening conferences.

The Shot Peener: Why is the Delta Hotel in Montreal a good location for the conference?

Prof. Lévesque: The shot peening conference typically attracts around 200 academics, industry leaders and students. The Delta Hotel offers a very cozy environment to host events that size. The conference will run three parallel sessions in rooms that are located on the same floor and are less than a 30-second walk from each other. The booths and the breaks will be located in a central foyer that connects to the meeting rooms. This will create a very intimate atmosphere and will promote exchanges among attendees, which is the aim of such gatherings.

The Delta Hotel is ideally situated in downtown Montreal. It is walking distance from the business city center, the historic section of Montréal and the Mont Royal park where nature lovers can jog or walk. The Delta Hotel Chef will prepare meals with locally sourced products so attendees will enjoy a Québecois culinary experience. The Delta Hotel will offer specially discounted rooms but, owing to its central location, attendees will have other hotel choices to meet their comfort and/or budget needs.

The Shot Peener: You are actively involved in shot peening research in your position as Chairholder of the Canada Research Chair in Multiscale Modelling of Advanced Aerospace Materials at École Polytechnique de Montréal. Why are you interested in shot peening research?

Old Montreal is within walking distance of the conference venue in the Delta Hotel.


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Prof. Lévesque: I was trained in composites research and I fell into the shot peening field by accident. In 2005, when I was a young academic, my colleague Marie Bernard, who was about to retire, asked if I wanted to look at some shot peening related issues with her colleagues, Claude Perron and Simon Larose, at the Aerospace Manufacturing Technology Centre. To be quite honest, I had never heard of shot peening. My first projects were to simulate the shot stream and its effects on residual stresses and roughness. I used some of the tricks I picked in composites to propose an original model that was among the first to introduce stochastic effects in the shot stream representation. I was also involved in peen forming simulation and obtained very interesting results. I proposed a shot peening research program at the research forum of the 5th Consortium for Research and Innovation in Aerospace in Québec and immediately gained the support of aerospace companies in Montreal.

I now work with several people on this project including two metallurgists, Prof. Myriam Brochu with Polytechnique and Prof. Philippe Bocher with École de Technologie Supérieure; one material scientist, Prof. Richard Chromik at McGill University; and my long-standing collaborator, Claude Perron, now with Centre Technologique en Aerospatiale. Dr. Hongyan Miao, my former PhD student, trains students and manages the project. We study and predict the effects of shot peening on the fatigue lives of aerospace parts. This is a truly multi-disciplinary research program where we look at both the modelling of the process (shot stream, macroscopic residual stresses induced) and the effects it has on microstructure (crystal plasticity simulations, development of multi-scale fatigue prediction models).

What makes me passionate about my shot peening research is that it is a multi-scale and multi-disciplinary problem that requires expertise in computational sciences, mechanics, metallurgy and materials sciences. It allows me to learn from my collaborators in numerous fields. The strong interest from our industrial partners is also a great source of motivation since I feel that the work I do is useful.

The Shot Peener: Your last comment brings us to the enviable relationship between the École Polytechnique de Montréal and the aerospace industry. Tell us about it.

Prof. Lévesque: As I mentioned earlier, Polytechnique is working with leading aerospace companies in Montreal. In collaboration with McGill University and École de Technologie Supérieure, we lead the most intensive shot peening-related collaborative research and development project in Canada. The project involves Pratt and Whitney Canada, Bell Helicopter Textron, L-3 Communications MAS, Héroux Devtek Landing Gear, Dorval Technologies, and the Centre Technologique en Aerospatiale. The project is funded by the industrial partners, the Consortium for Research and Innovation in Aerospace in Québec, Mitacs, and the National Sciences and Engineering Research Council (NSERC). The project has been labelled the "MANU-508" at the Consortium for Research and Innovation in Aerospace in Québec.

MANU-508 funded the procurement of a full-scale, fully robotic shot peening machine for research projects at Polytechnique. A Canablast-Genik-Fanuc consortium supplied the machine and Electronics Inc. donated two MagnaValves and controllers, including the new MagnaValve for non-ferrous media. Polytechnique is also using the shot peening machine in peen forming projects with Bombardier, Sonaca and Airbus (UK).

The Shot Peener: How did these relationships come about?

Prof. Lévesque: I approached Pratt & Whitney Canada, Bell Helicopter Textron, L-3 Communications MAS, Héroux, Bombardier, Sonaca, and Airbus and convinced them to invest in shot peening-related research. Also, collaborative research and development in Canada is funded by the NSERC Collaborative and Research Grant program that offers: 1) No limitation on funding, 2) No application deadlines, and 3) High success rates (+95%). The program requires 1$ cash + 1$ in-kind industrial commitment and NSERC provides 2$ cash. So when you have five companies who donate each 1$ cash + 1$ in-kind, you end up with a project worth 15$ cash and 5$ in-kind for research. This is a fabulous leveraging system (15 to 1!) and a very successful program in Canada.

The Shot Peener: Thank you for your insights, Prof. Lévesque. We look forward to learning more about your research and ICSP13 in future issues of *The Shot Peener*.

The shot peening machine at École Polytechnique de Montréal is used for academic research and testing projects for the aerospace industry in Montreal.

NanoPeening® by Winoa

WINOA, formerly Wheelabrator Allevard, is a world leader in abrasion and cutting technologies for the metal and stone industries. Innovation is a guiding principle for Winoa and the company is marketing their new process called NanoPeening® that is of special interest to the shot peening industry.

NanoPeening® is a surface enhancement technology developed and patented by Winoa. It enables the surface transformation of metals by reducing grain size down to a nanometric scale. According to Winoa, NanoPeening® can achieve improvements in hardness, abrasive wear, fatigue life and corrosion resistance that aren't possible with a conventional shot peening operation. NanoPeening®, however, is a mechanical process that doesn't use chemicals or nanometric particles and it is done at room temperature. The equipment to perform NanoPeening® looks like a conventional shot peening machine from the outside. The difference is in the way the treatment is carried out, employing a precise combination of parameters that are accurately controlled and adjusted to both the material and shape of the component being treated.

Winoa has investigated industrial applications for the new process and has qualified:

- Tools - forging dies, casting dies, plastic molds, rolls
- Mechanical parts - automotive and aerospace gears and pinions
- Stainless steel hardening - tubes, dosing pumps

The benefits of NanoPeening® include:

- Reduces costs
- Increases performance
- Allows the downsizing of mechanical parts
- Replaces thermochemical treatments when anti-corrosion or treatment times are an issue
- Surface hardness increased by 200%
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- Up to 200 µm transformed thickness
- Progressive transition from surface to core structure

Constance Morel, a Research and Development Process Engineer for Winoa, and Mario Guagliano, a Professor with the Department of Mechanical Engineering at Politecnico di Milano (MECC), have been working together to apply the modeling competences of MECC to the NanoPeening® process. They have prepared a report on some of their work for the readers of *The Shot Peener*. The paper's Introduction has been reprinted here and the complete paper is available for download in the library at www.shotpeener.com (paper number 2014001).

Surface Nanostructuring through a Technique Derived from Shot-Peening: Recent Advances

Constance MOREL (WINOA)
co-author: Pr. Mario GUAGLIANO (Department Mechanical Engineering, Politecnico di Milano)

INTRODUCTION

Over the past decades, ultrafine-grained materials have attracted considerable scientific interests, especially nanocrystalline materials, whose grain size inferior to 100 nm conveys superior mechanical, physical, and chemical properties compared to conventional coarse-grained materials. It is well known that most of failures of engineering materials (such as fatigue fracture, fretting fatigue, wear, corrosion, etc.) are very sensitive to the structure and properties of material surface, and in most cases material failures occur on the surface. As a consequence, a material exhibiting a nanostructured surface is expected to be much less likely to undergo such damages without changing the chemical compositions.

Many techniques have been developed to achieve surface nanocrystallization. Referred to as Severe Plastic Deformation (SPD) techniques, they all rely on the plasticity of metals and lead to a mechanically induced nanostructuration of the surface. Some of them can be referred to as "bulk treatments" as they aim at transforming the whole volume of a part They include ECAP (Equal Channel Angular Pressing), HPT (High Pressure Torsion) or drilling. On the other hand, some techniques focus on the surface: SMAT (Surface Mechanical Attrition Treatment) or USSP (Ultrasonic Shot Peenng), ball milling, sliding wear.

While those processes were developed at laboratory scale and are hardly compatible with up-scaling for application to mass-production, Severe Plastic Deformation and the resulting surface nanostructuring can also be achieved through a technique derived from Shot-Peening called NanoPeening®. In most cases, Shot-Peening carried out longer or stronger than usually leads to "over-peening", which is detrimental to the material, inducing cracks and surface degradation without any change in the microstructure. In the last few years it was discovered that it is possible, under specific conditions, to pass over these effects and reach a nanocrystallised state of the surface. NanoPeening®-type treatments thus allow for the fast generation of a thick layer (several tens of micrometers) characterized by a gradient in grain size from a nanocrystalline microstructure at the surface to the conventional core structure. Like all SPD techniques, the nanostructured layer is produced "in-situ", i.e. without any external addition like a coating, but this new treatment differs from the processes mentioned earlier in that it offers a real potential in industrial applications with high productivity, reliability and reproducibility. It is also very flexible, as a large range of shapes, sizes and steel grades can be treated.

This article aims at giving a description of NanoPeening® process, including the modeling works carried out with Pr. Guagliano's team from Politecnico di Milano: using a Finite Elements method, they developed a program that allows for an estimation of the nanostructured layer created by the treatment, for a given set of process parameters.

The complete paper is available for download in the library at www.shotpeener.com (paper number 2014001).

Quality, Service, Price: The Malyn Difference

WHEN 50-YEAR-OLD abrasive sand-blasting equipment manufacturer Pressure Blast Manufacturing needs boron carbide nozzles and inserts, the company turns to Malyn Industrial Ceramics, Inc. For more than 15 years, the Windsor, Connecticut-based company has relied on Malyn's high-quality, durable line of products to give it a distinct advantage over its competition.

"Malyn's products separate it from other manufacturers and make it a valuable business partner," says Jodie Smith, project manager for Pressure Blast. "All companies can appreciate a well-manufactured product and knowing it will be competitively priced and delivered on time. That's why we'll continue to do business with Malyn for years to come."

A small company with a large business.

After working for many years in the refractory technology industry, Michael Malyn formed Malyn Industrial Ceramics, Inc. in 1986 with his wife, Patricia. Today, the thriving family-owned company manufactures custom-made nozzles and other boron carbide components to meet the needs of its worldwide customers, shipping more than 50,000 nozzles annually.

"Producing boron carbide and tungsten carbide nozzles is our only business," says Michael Malyn. "Our customers come to us directly for answers and for solutions. We work very hard to give them a product that's better than anyone else's, is competitively priced and is made right here in the U.S.A."

Boron carbide is third in hardness only to diamonds and cubic boron nitride, so it makes for a durable and dependable quality product that Malyn stands behind 100 percent. Boron carbide nozzles come in all sizes, shapes and styles, and are used to process everything from golf balls to dentures to stonewashed jeans. They are also used to help prepare surfaces such as buildings and bridges for painting and cleaning by sandblasting.

With Malyn's purchase in 2005 of Super Titan, a 75-year-old manufacturer of tungsten carbide nozzles used primarily in the metal finishing and painting and contracting industries, the company is able to offer its customers yet another cost-effective nozzle option. Malyn also offers toll hot pressing, grinding and machining, custom designs and services and more.

What sets Malyn apart from similar companies?

"I look for companies that are able to 'think outside the box' and that is what I have found with Malyn," says Christen Reinke, President of Industrial Supply, Inc., of Twin Falls, Idaho. "Malyn enables me to offer my customers a huge variety of both standard and custom, USA-made nozzles. Mike will even drop ship direct to customers so I don't have to waste valuable time and resources."

All of Malyn's manufacturing is done at the company's 15,000-square-foot plant in its Clarence, New York headquarters (just outside Buffalo), allowing Malyn to produce a variety of sizes and styles of boron carbide nozzles. The company can easily accommodate specialty sizes and styles to meet unique customer needs, and all orders are typically shipped within 48 hours. By controlling the entire process — from computerized order tracking to mold making and manufacturing, finishing, final inspection and shipping — Malyn ensures its customers receive exceptional value for their nozzle or insert investment. Malyn's competitive pricing makes its products very affordable, and no order is too small.

"Our customers know they can come straight to the owner of the company with any problems and concerns and they will immediately be addressed," says Michael Malyn.

In 2006, Michael and Patricia Malyn's daughter, Christina Malyn – who grew up around the business and knows it well – joined the company in a full-time capacity, ensuring the company will be a vital resource for its worldwide customers for years to come.

To reach Malyn Industrial Ceramics by phone, call (716) 741-1510; by fax, call (716) 741-8402; by email at sales@malyn.com; on the web at www.malyn.com or by mail at 8640 Roll Road, Clarence Center, New York 14032.

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Standard Questions

A manufacturing engineer with a medical device company has questions on the best specification for her company's shot peening process, how to prepare drawing prints for a shot peening job shop, and how to verify the shot peening process.

AN EDITORIAL CONSULTANT with SAE Aerospace Material Specifications (AMS) recently forwarded me an email from a Senior Manufacturing Engineer (let's call her SME). Even though she works for a medical device manufacturer, SME's questions and concerns are relevant to other companies, especially those that outsource shot peening and/or have recently received the responsibility for the shot peening program in their company. Here is SME's email:

> SME: *We have a part that's currently in production that calls out shot peening per AMS-S-13165. This part came from a mergers and acquisition project that the previous company created. I researched the standard and found on the SAE website that the latest version of AMS-S-13165A has been cancelled. So is this standard still applicable? Which version is applicable? Or is there another more relevant standard that we should use?*
>
> *We are a medical device maker. The shot peening process is outsourced. Our shot peening vendor tells us that we need to call out their process number, which does not give the details of the process parameters. What is a typical shot peening call out/drawing spec?*
>
> *We will also need to verify the output of the shot peening. The Almen strip provides a good indication as to the process and setup. To help verify the effect of the process on the part, we will need another verification method. Is X-Ray diffraction the typical applicable test? Is there a limitation to the size of the part? Our typical part is .200" in diameter and between 6" to 12" long.*
>
> *Thank you in advance for your response!*

I advised SME that most organizations migrate to AMS 2430 from AMS-S-13165 (canceled) while some continue to use the canceled spec (not common, but some do). I then forwarded the email to Scott Hatfield, a Senior Manufacturing Engineer with Medtronic. Scott is an expert in shot peening validation for medical device manufacturers.

> Scott Hatfield: *Sounds like you are in a common situation that plagues many companies in the post-merger environment. I will add some additional details to the good advice Jack has already provided to hopefully help you navigate your way though this transition.*
>
> *First, as Jack instructed, historically most organizations will migrate to AMS 2430 from AMS-S-13165. This migration can be achieved in many different ways, depending on your validation and design change policies. This could be as simple as a memo to file or design change rationale or as complex as performing fatigue testing, comparing the new data to baseline data as part of a full-blown re-validation. If your choice is to stay with the cancelled AMS-S-13165, it is always recommended to use the latest revision or the revision that was active at the time of cancellation unless a specific revision is stated on the part print.*
>
> *You had asked if there is a more applicable standard for what you are peening. I suggest that you consider using SAE J3020 (Medical Device Shot Peening). This is a new shot peening specification that I sponsored as an active, long-term member of the medical device industry. I noticed a void in this area of our industry and I created it to address the needs of the medical device industry and the requirements of the FDA. Without knowing exactly what you are peening, (implant or non-implant) and to what level of compliance you are currently targeting, it is hard to give you a definitive answer to what is best for your needs. However, I feel confident that if you are peening medical devices, SAE J3020 will supply the guidance and requirements to meet your needs and the requirements of the FDA more completely than what can be achieved by either AMS-S-13165 or AMS 2430.*
>
> *As for your vendor telling you that you need to call out their process number on your prints: I would advise you to never put a vendor's call out on your prints. This will only create a cornering of the market for your vendor, making them the only source that can peen your parts without a design change and a re-validation. This would put them in control of your product sourcing due to the FDA regulation on changing processors and procedures. I would suggest requiring them to meet the peening specification that you choose to list on your prints. If their internal process number conforms to that requirement, it can be added as*

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a purchase order note along with listing the specification that you noted on your print. This will assure that both specifications are delivered. If your vendor insists on their number being listed on the print and you don't want to be tied down to a single vendor, I would suggest finding an alternative vendor. There are many out there that are willing to peen to international standards and will execute to meet your requirements and supply you with all of the process information that you request.

You wrote, "What is a typical Shot Peening Call Out/ Drawing Spec?" Typically, the shot peening specification is listed as shot peening per (AMS-xxxx), followed by the required media specification (AMS-xxxx), a definition of the area requiring shot peening, the masked area, and the optional area followed by a coverage requirement per SAE J2277.

As for verifying the output of the shot peening: X-Ray Diffraction is a viable test and can be performed on small and large areas alike. However, you must know what depth of residual compressive stress is required to meet design intent. This is typically unknown and undocumented, making it a test that is not as widely used to verify the peening process as you may think.

Typically fatigue testing is the more commonly used option to verify the peening process in the medical device industry. This testing is performed already as part of the FDA submission process of new medical device implants with a defined requirement of cycle and load requirements. If the peening process passes the fatigue test, the peening operation is delivering the required results to meet design requirements. The Almen strip tests, besides being used to create a saturation curve, are used to determine shot peening intensity. Almen strip tests are used to establish the equipment's capability to repeat the required energy in the shot stream to produce a constant and repeatable improvement in fatigue life. It is a vital element in the validation of the peening process. It is also a vital part of the continued process monitoring to assure quality in the peening process.

I hope this helps you better navigate through this transition and if you would like additional information, please feel free to contract me with your questions.

We received a very nice "thank you" from SME and I look forward to meeting her someday; maybe at the next Shot Peening workshop in California.


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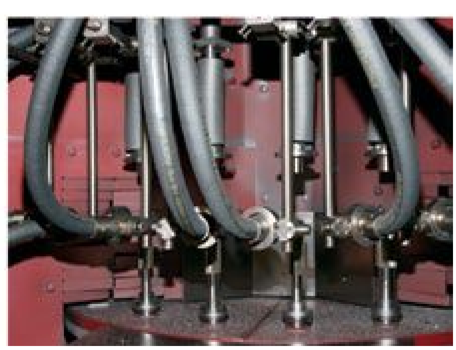

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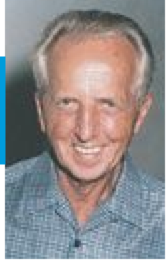

ACADEMIC STUDY
by Dr. David Kirk | Coventry University

Quantification of Shot Peening Intensity Rating

INTRODUCTION

This article is complementary to the previous TSP article– "Quantification of Shot Peening Coverage." As such, it considers the second of the two most important shot peening requirements specified by customers. "Peening Intensity" as a phrase is ambiguous, since most engineering and scientific intensity quantities refer to something per unit area. Addition of "rating" yields "Peening Intensity Rating" (PIR) as a disambiguous quantity. "Rating" implies the application of some sort of criterion appropriate to the situation; e.g., golf rating, theatre rating, weather rating. The criterion for peening intensity is a particular point on a 'saturation curve'.

Shot peening intensity is rated by a point, P, on a 'saturation curve', see fig.1. This point has, of necessity, two coordinates – H and T. H is the 'h-coordinate' value of deflection at a 't-coordinate' value of peening time, T. The definition of 'T' is that the arc height increases by 10% when T is doubled. The magnitude of H on a particular curve therefore depends upon the location of T. Peening intensity rating increases with increase in the magnitude of H.

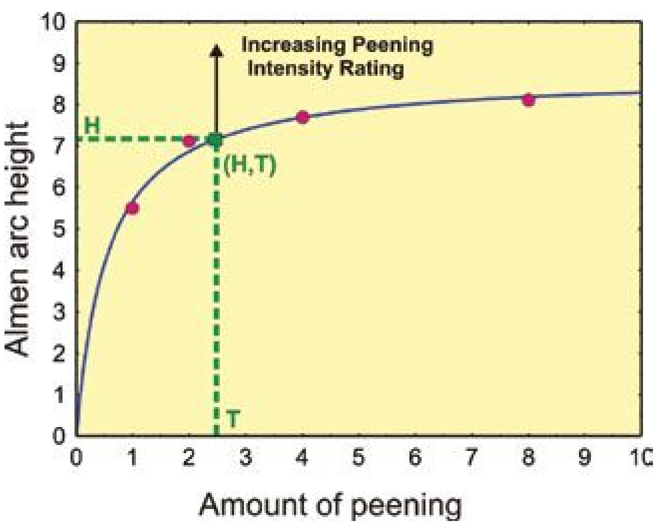

Fig.1. Typical peening intensity curve with derived Peening Intensity Rating, H.

Shot peening one major face of an Almen strip induces bending of the strip. This bending of the strip is created by the plastic extension of the peened face. It is sometimes stated, erroneously, that the strip bending is solely caused by residual compressive stresses in the peened surface layer. In creating strip bending, two mechanisms are involved. The first is plastic deformation of the surface being peened – which causes permanent bending. The second is a consequence of the first – residual compressive stress in the peened surface which causes further, semi-permanent, bending. Both of these mechanisms are beneficial to the service performance of components.

It has been shown (ICSP2, Kirk, "Behavior of Peen-formed Steel Strip on Isochronal Annealing") that the two contributions to strip bending (plastic deformation and residual compressive stress in the peened surface layer) are approximately equal in magnitude. This equality was indicated by the 50% reduction of arc height that occurs when peened Almen strips were stress-relieved by annealing. This effect is illustrated, schematically, by fig.2.

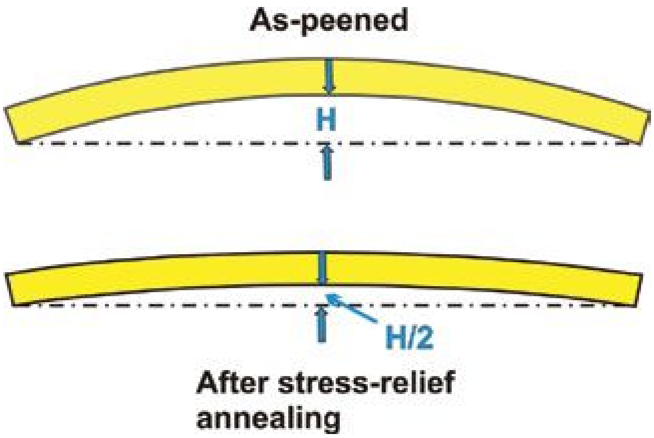

Fig.2. Halving of Almen strip deflection after stress-relief annealing.

BENDING OF ALMEN STRIPS

Bending of Almen strips, to generate arc height deflection, involves two components:

(1) Permanent bending - due to the plastic extension of the peened surface and
(2) A removable bending moment - resulting from the residual compressive stress in the plastically-deformed surface layer.

This bending moment, M, is illustrated by fig.3.

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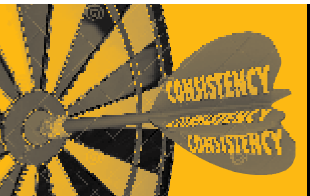

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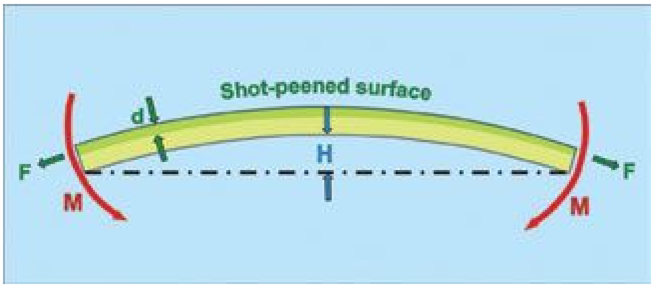

Fig.3. Bending of an Almen strip due to induced bending moment, M.

Plastic expansion of the peened surface (due to cold-working) extends to a depth, d. This forces the strip to bend - permanently. This bending is resisted by the strip, resulting in compressive residual stress to the depth, d. Compressive residual stress in the peened surface generates an outward force which contributes roughly half of the observed deflection, H.

The concept of a combination of permanent, plastic, bending and removable, elastic, bending is important for the rating of peening intensity – and for the whole process of shot peening. As a mental exercise consider the following analogy. A thin flat strip of aluminum can be bent, using two hands, to form an arc. If only small forces are being applied the strip is only suffering elastic bending and will return to its flat shape when the forces are removed. If, however, the applied forces reach a critical limit the strip will become permanently bent. Removing the applied forces will only reduce the bending. The strip will have suffered some permanent bending and will be left with compressive residual stress in the convex face.

Both of the bending components involve energy being stored in the peened surface – either as cold-work energy or elastic bending energy. Cold-work is force multiplied by distance so that its units are Nm. Bending moment, **M**, is force, **F**, multiplied by the distance through which that force acts – so that its units are also **Nm**. The distance involved is approximately that from half the depth of the compressed layer to the center of the Almen strip.

The units for work done are **N*m** (force multiplied by the distance through which it acts). Hence the work done in plastically deforming the strip surface has units of **N*m**. These are the same as those for the kinetic energy of impacting particles (as described in the previous TSP article). We know that the units for bending moment, **M**, are also **N*m** (again force multiplied by the distance through which it acts). Hence the units of the bending moment induced by compressive residual stresses are **N*m** - which are the same as those of the kinetic energy of the impacting particles and also for the work done as plastic deformation.

Arc height has a single unit - of distance, **m**. This is the deflection, **H**, at a particular point on an 'arc height versus amount of peening' curve. Hence:

$$H = M/K \qquad (1)$$

Where **M**, the kinetic energy that has been effectively absorbed, has units of **N*m** and **K** is a constant (for a given thickness of Almen strip) and has units of **N**.

ABSORPTION OF SHOT STREAM KINETIC ENERGY

We can estimate (a) the amount of kinetic energy that a given shot stream delivers to an Almen strip surface, (b) the amount of kinetic energy that is required to generate a known amount of bending of an Almen strip and (c) compare these quantities with one another.

(a) Amount of kinetic energy being delivered by a shot stream

A shot stream delivers a known amount of kinetic energy per second. This amount, **S**, is given by:

$$S = ½FR*v^2 \qquad (2)$$

where **FR** is the feed rate.

Equation (2) is simply a version of the familiar $½m*v^2$ expression for kinetic energy of a particle.

The total amount of kinetic energy, **TA**, provided in a given time, **t**, is therefore given by:

$$TA = ½FR*t*v^2 \qquad (3)$$

where **FR** is the feed rate and **t** is the time of peening.

Assume, for the sake of argument, that a shot stream is delivering 0.02 kg of shot per second (1.2 kg per minute) whose velocity is 50 $m*s^{-1}$. Using equation (3) we get that when **t** equals 1 second:

$$TA = ½*0.02\ kg*s^{-1}*1s*50^2\ m^{2}*s^{-2}$$
$$= 25\ kg*m^{2}*s^{-2}\ \text{or}$$
$$TA = 25\ N*m$$

This is the total amount of kinetic energy delivered by the shot stream in one second. Only a fraction of the shot stream actually impacts an Almen strip placed in its path. That fraction can, however, be estimated for a given geometry of the shot stream.

(b) Amount of kinetic energy required to generate a known amount of bending

Trying to estimate the required amount of energy using plasticity and elasticity theories simultaneously is complicated. The problem is greatly simplified by assuming that all of the required energy is for elastic bending. Alternatively we could estimate the energy required to elastically bend to a displacement **h/2** and then simply double that amount (to allow for the plastic deformation requirement).

Assume then that an Almen A strip is elastically bent to an arc height, **h**, of 0.250 mm. The bending moment (and hence amount of kinetic energy required) can be estimated

by employing the standard beam-bending formula that **M = E*I/R** where **E** is elastic modulus, **I** is the second moment of area (width times thickness cubed divided by twelve for a rectangular strip). **R** equals **L^2/8h** (for a circular arc) where **L** is the strip length. Substituting for **R** gives that:

$$M = E*I*8h/L^2 \quad (4)$$

Using **E** equal to 210 GPa, **h** equal to 0.250 mm and **L** equal to 40 mm, equation (4) predicts that:

$$M = 1.01 \text{ N*m}$$

(after multiplying by 1.125 to allow for cross-wise bending).

(c) Comparison of (a) and (b)

There is a very large difference between the 25 N*m of kinetic energy estimated for **TA** and the 1 N*m estimated for **M**. This confirms that only a small fraction of the kinetic energy available from the shot stream is converted into Almen strip bending. Three reasons are evident: (1) only part of a standard shot stream will actually strike the strip, (2) not all of the kinetic energy of the particles striking the strip is absorbed – some is retained as the kinetic energy of the rebounding shot and (3) most of the energy causing plastic deformation is converted into heat.

Let us assume that (1) that 80% of the shot stream strikes the strip, (2) 50% of the kinetic energy is retained as rebound energy and (3) that 90% of the absorbed energy is converted into heat. This gives that the shot stream's contribution to strip bending energy, **C**, is given by:

$$C = 25 \text{ N*m} \times 0.8 \times 0.5 \text{ X } 0.1 \text{ or}$$
$$C = 1 \text{ N*m}$$

This value of 1 N*m is now the same as that predicted for **M**. It must be confessed that this close similarity is not accidental – the assumed values were 'tailored to fit'. Nevertheless these values were not unreasonable. This example shows that we can equate shot stream energy supply and bending requirement for realistic practical examples.

PROGRESSIVE ABSORPTION OF SHOT STREAM KINETIC ENERGY

The absorption of shot stream kinetic energy increases with the time of its contact with an Almen strip. In other words the longer we peen the greater will be the amount of absorbed energy. The total amount of kinetic energy, **TA**, which is delivered by a shot stream in a peening time **t** is given by equation (3). If the bending force, **F**, increased at a constant rate then the arc height would also be predicted to increase linearly with peening time. This is obviously not the case – the rate of increase of arc height decreases with peening time – as is evidenced by the actual peening intensity curve given as fig.4.

Fig.4. Typical Peening Intensity Curve.

The force, **F**, which creates bending due to residual stress, is given by:

$$F = \sigma * A \quad (5)$$

Where **σ** is the average residual stress in the peened surface layer and **A** is the cross-sectional area in the bending direction.

A bending moment, **M**, is generated by the force, **F**, acting over a distance **(t/2 – d/2)** where **d** is the depth of the compressed peened surface layer – see fig.5.

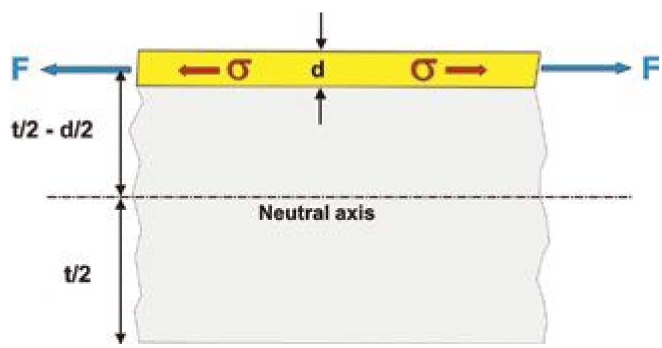

Fig.5. Section of peened Almen strip with bending force, F, acting over a distance (t/2 – d/2).

Strictly speaking, there are two bending forces at work: F_L acting in the longitudinal direction and F_T acting in the transverse direction. F_L promotes longitudinal bending whereas F_T promotes transverse bending.

The longitudinal bending moment, M_L induced by a compressed surface layer of depth, **d**, is given by $M_L = F*(t/2 – d/2)$ but **F = σ*A** and **A = W*d** (where **W** is the width of the Almen strip). Hence we have that:

$$M_L = \sigma*W*d*(t/2 – d/2) \quad (6)$$

For the transverse bending moment, M_T, with a strip of length **L** the equivalent equation is that:

$$M_T = \sigma*L*d*(t/2 – d/2) \quad (7)$$

AVERAGE LEVEL OF RESIDUAL STRESS IN COMPRESSED SURFACE LAYER

The average level of residual stress is a very important quantification parameter – determining both the magnitude of component property improvement and the degree of either beneficial or unwanted component distortion. In order to estimate this average stress we must first know the residual stress profile – just as we must establish a saturation curve before we can estimate peening intensity. Analyzing a residual stress profile for average stress is best carried out by estimating the area of the residual stress profile and dividing that area by the depth of the compressed layer. Three applicable techniques are described in this section. They are: Direct Graphical Analysis, Computer-based Graphical Analysis and Calculus-based Graphical Analysis.

Direct Graphical Analysis

This method is based on summing the number of unit rectangles that lie within the area to be estimated. The unit's size must be small compared with the area being estimated – to ensure reasonable accuracy. Fig.6 shows a unit rectangle as the 'counting unit'. The area of the unit shown happens to be -50 Nmm^{-2} (depth) multiplied by 0.02mm (width). That area is therefore exactly -1 Nmm^{-1}. It can be seen in fig.6 that the area of the profile comprises a mixture of (a) units that lie completely within the area and (b) units overlapping the stress profile so that they are part inside and part outside. The trick is to add half of these overlapping units to all of those completely within the area. As an example consider the top row of unit rectangles in fig.6. There are 23 unit rectangles completely within the area and 2 that are only partly within the area – hence we count that row as 24 (23 plus 2/2). Successive rows count up as 23, 22, 21, 19, 19, 17, 17, 15, 14, 12, 10, 6 and 1. Adding up the 14 row counts gives 220 units as an estimate of the profile's area.

The average residual stress in the profile σ_{AV} is obtained by dividing the measured area by the width, **d**, of the profile. For this example **d** is 0.5mm. Hence the average residual stress is - 440 Nmm^{-2} (- 220 Nmm^{-1} divided by 0.5mm).

Computer-based Graphical Analysis

This method uses advanced mathematical software (such as the author's favorite – "MathCad") but requires an input of the equation that defines the residual stress profile. In a previous article by the author ("Curve Fitting for Shot Peening Data Analysis", TSP, Spring, 2002) it was shown that the normal shape of a stress profile can be assigned a simple cubic equation. Fig.15 of that article is recreated here as fig.6 – albeit with some additions to emphasize area estimation. The equation of this particular residual stress profile is that:

$$\sigma = -1.3336*10^{4}*x^{3} + 1.4669*10^{4}*x^{2} - 3000.5*x - 500 \quad (8)$$

where **x** is the distance below the surface.

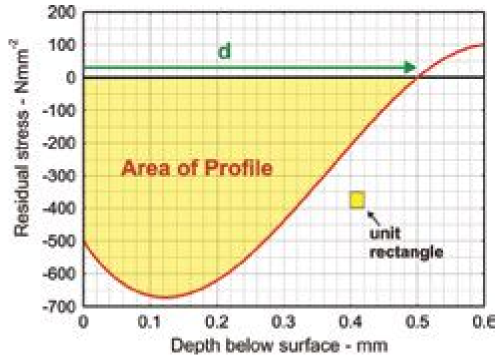

Fig.6. Residual stress profile emphasizing profile area and unit rectangle.

Having inputted the equation of the residual stress profile the computer program is then told to sum the area between limits of 0 and 0.5. Using the summing facility of "MathCad" the area is given as -222.2 units which on dividing by 0.5 (as in the previous method) estimates the average residual stress to be -444.4 Nm^{-2}. That is only 1% different from the partially-subjective method used previously and has the advantage of being completely objective. The summing facility that the computer uses is exactly the same as that of the direct graphical analysis method – the difference being that the 'unit rectangle' is relatively minute to that many millions of units are summed in a fraction of a second.

Calculus-based Graphical Analysis

This method also requires knowing an equation that defines the residual stress profile. The equation is then 'integrated'. For equation (8) the integral is:

$$\sigma = -1.3336*10^{4}*x^{4}/4 + 1.4669*10^{4}*x^{3}/3 - 3000.5*x^{2}/2 - 500x \quad (9)$$

The area defined by the integral equation (9) is obtained by simply substituting 0.5 for **x**. This gives that the estimated area is -222.2 – exactly as estimated using computer software – yielding -444.4 Nmm^{-2} as the average residual compressive stress.

QUANTIFICATION OF ARC HEIGHT DUE TO RESIDUAL STRESS

Equations (6) and (7) can now be used to derive an equation for that part of the arc height that is due to residual stress. This derivation uses the relationship that **M = E*I/R** where **E** is elastic modulus, **I** is the second moment of area (width times thickness cubed divided by 12 for a rectangular strip) and **R** is the radius of bending together with the relationship between arc height, strip dimension and **R** described in previous articles. Substituting those relationships into equations (6) and (7) gives that:

$$h_L = 1.5*\sigma*L^{2}*d*(t/2 - d/2)/(E*t^{3}) \quad (10)$$

and

$$h_W = 1.5*\sigma*W^{2}*d*(t/2 - d/2)/(E*t^{3}) \quad (11)$$


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where h_L and h_W are the contributions to arc height from longitudinal and width-wise bending respectively, σ is the average residual compressive stress, **L** and **W** are the longitudinal and width-wise distances between the ball supports of the Almen strip and **t** is the strip thickness.

Adding h_L and h_W gives us the total arc height deflection **H** (that measured by an Almen gage). Hence:

$$H = 1.5*\sigma*(L^2 + W^2)*d*(t/2 - d/2)/(E*t^3) \qquad (12)$$

The longitudinal and width-wise distances, **L** and **W**, are fixed quantities as is the thickness, **t**, of a given type of Almen strip. Hopefully, the elastic constant, **E**, is also a fixed quantity. Using **L = 31.75 mm**, **W = 15.87 mm**, **E = 210,000 Nmm^{-2} and t = 1.295 mm** (the thickness of Almen A strips) equation (12) simplifies to:

$$H_A = 4.144*\sigma*d*(0.6475 - d/2)/1000 \qquad (13)$$

If the average compressive stress is independent of the depth then equation (13) predicts that the arc height stress contribution will only depend on the depth, **d**, of the profile. Fig.7 plots the equation, together with the curves for Almen N and C strips, assuming a constant average compressive stress of 400 Nmm^{-2}. The curves indicate several significant features. These include: (1) that the arc height rises in a parabolic fashion with increasing layer depth reaching a maximum when the depth is half the strip's thickness – thereafter the arc height falls as some force is now acting in the opposite bending direction, (2) the depth of layer for a given arc height is in the ratios 1:3:10.5 for N, A and C strips respectively.

It should be noted that the measured total arc height for a given peened Almen strip is increased because of the plastic deformation contribution to bending.

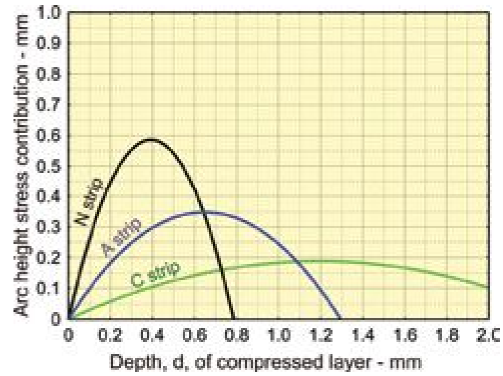


Fig.7. Contribution to arc height due to residual compressive stress.

Measurements of the average stress in the compressed surface layer are not commonly available – unfortunately, since equation (12) assumes that measured arc height is directly proportional to the level of stress. Equations (6) and (7) indicate that the peening-induced bending moment (and hence arc height) are directly proportional to the depth of the compressed surface layer.

Some interesting graphical evidence is available: "Depth of Compression versus Peening Intensity" (EI Library of graphs). This indicates that the depth of compression is linearly related to the peening intensity. The converse must therefore be true – that peening intensity is proportional to the depth of the compressed layer. Fig.8 interpolates some of the information in the graph (which includes three steels of different hardnesses) to highlight the significance of Almen strip hardness variation. The graph converts the published data into metric units and uses the data up to its maximum (for three steels) of 0.711 mm (0.028A).

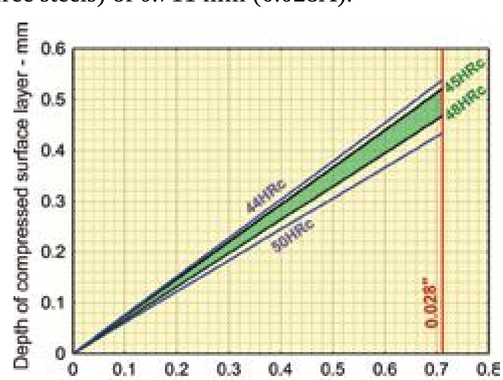


Fig.8. Derived variation of Peening Intensity with Almen Strip Hardness.

DISCUSSION

This article has used basic beam bending principles to quantify the relationship between the several factors affecting measured Almen arc height – and hence peening intensity. In spite of the simplifications that have been adopted the quantitative relationships that have been derived tally with practical experiences.

Equation (12) epitomizes the several factors that quantitatively influence derived Almen peening intensities. Measurements of arc height, **H**, are affected by the precision and bias of the measuring technique; the distances between the gage ball supports, **L** and **W**, are critical and ball wear is an established concern; strip thickness, **t**, appears in both numerator and, as a cube, in the denominator; elastic modulus, **E**, controls **H** inversely (but is not included in strip specifications) and by the average stress, σ, in the compressed surface layer. Converting a set of **H** measurements into a 'saturation curve' and deriving the peening intensity point have been thoroughly discussed in other articles in this series.

Specifications allow a range of 45 to 48 HRc for Aero-grade Almen strips and 44 to 50 for Auto-grade Almen strips. It can be seen in fig.8 that the higher-grade strips reduce the consequent variation of the derived peening intensity value by a factor of two. More direct experimental work is, however, needed in order that the several equations in this article can be substantiated.

Innovations in Turbine Blade Manufacturing

Integrally Woven Fiber Architecture for Composite Turbine Blades

John H. Glenn Research Center, Cleveland, Ohio

Composite turbine blades are currently fabricated by laying up multiple layers of fibers in the form of either unidirectional prepregs or thin woven cloth. Composites formed in this manner have poor through-thickness strength. It is also difficult, if not impossible, to form trailing edges as thin as necessary for optimum engine performance.

A method was developed to produce integrally woven preforms of reinforcing fibers for ceramic composite turbine blades. The preforms contain reinforcing fibers in a 3D arrangement that avoids failure by delamination, and allows formation of thin trailing edges.

Two versions of the design were developed. The complex nature of the weave structures in the walls of the airfoil and in the trailing edge region mandates the use of a Jacquard head loom to produce the preform, rather than the more common Dobby loom. In the first version, a reduced weft fiber count in the tapered trailing edge region was produced by drawing weft tows out of the woven preform during weaving, and removing them by cutting after weaving. In the second version, the paths of the weft fiber tows were modified to make them turn in a staggered pattern within the trailing edge region, thus avoiding the need for cutting any tows.

The 3D arrangement of the fibers in walls and the trailing edge allows the design of hollow blades that can contain high-pressure cooling air without the danger of splitting the trailing edge region. It also allows formation of thinner trailing edges, and can be optimized for different loads in different applications. The 3D arrangement also can be adjusted to produce blades that taper in cross-section from the base to the tip. Formation of the trailing edge without cutting circumferential fibers gives more uniform surface texture and reduced manual steps in producing the preform.

This work was done by Brian Cox and David Marshall of Teledyne Scientific Co. for Glenn Research Center.

Novel Capability Enables First Test of Real Turbine Engine Conditions

Argonne National Laboratory

Manufacturers of turbine engines for airplanes, automobiles and electric generation plants could expedite the development of more durable, energy-efficient turbine blades thanks to a partnership between the U.S. Department of Energy's Argonne National Laboratory, the German Aerospace Center and the universities of Central Florida and Cleveland State.

The ability to operate turbine blades at higher temperatures improves efficiency and reduces energy costs. For example, energy companies estimate that raising the operating temperature by 1 percent at a single electric generation facility can save up to $20 million a year. In order to achieve the highest temperatures of 1,832 degrees Fahrenheit in engines, metallic turbine blades are coated with ceramic thermal-barrier coatings and actively air cooled, which together allows operating temperatures exceeding the metal's melting point. Adding to these extreme conditions, during high-temperature operation, blade rotation induces thermo-mechanical stresses throughout the blade components.

Because of the difficulty of monitoring engines in operation, most manufacturers test blades either after flight or rely on simulated tests to give them the data on how the various coatings on the blades are performing. Until now, creating an accurate simulation has been out of reach, but the team knew that if they could build it, industry would come calling.

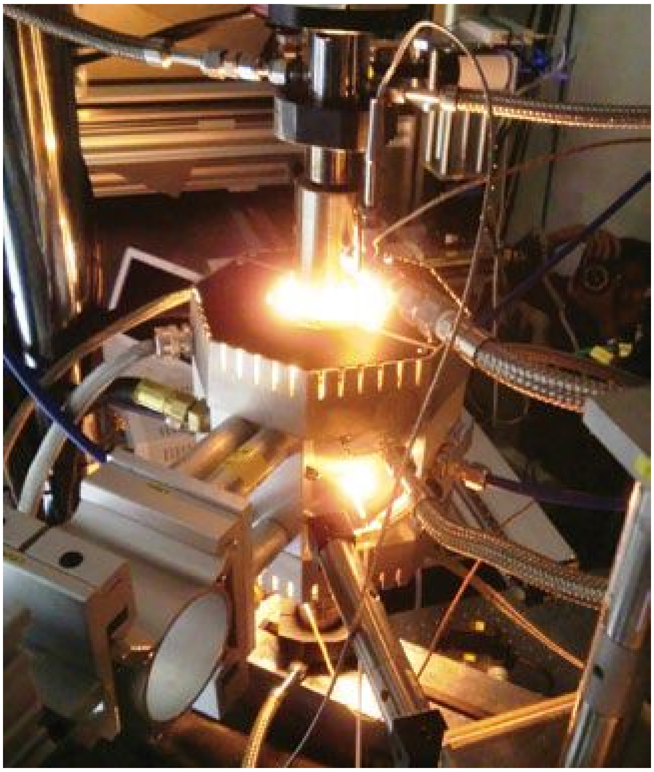
"While the idea sounded impossible, we had a team of willing collaborators with complementary skills as well as excellent students who were motivated to take on the challenge," said Seetha Raghavan, an associate professor of mechanical and aerospace engineering at the University of Central Florida and a co-author on the team's paper outlining the novel technique in the July issue of *Nature Communications* magazine.

The research team has succeeded in developing a new in-situ facility for use at Argonne's Advanced Photon Source (APS) that for the first time accurately simulates these extreme

turbine engine conditions. In particular, the Florida team developed an improved furnace system and the German team developed a novel coolant system to add to the mechanical testing system at Sector 1 of the APS, where the high-energy X-rays (E~86 keV) were able to penetrate all layers of a coated test blade.

This goes beyond any other in-situ capabilities to allow the influence of temperature, stress and thermal gradients to be studied together. This enables for the first time scientists to view the microstructure and internal strain in both the substrate and thermal barrier coating system during real operating conditions and in real time. The team captured high-resolution images of evolving strains and hopes in future experiments to pinpoint when and where defects start. This would allow for an accurate lifespan estimate on material and to improve the process for applying ceramic thermobarrier coatings. This could help industry in a couple of ways. It could potentially improve the quality of plasma spray applications and reduce the cost of the more expensive higher quality electron beam physical vapor deposition (EBPVD) applications.

"This integrated approach allows us to simulate the engine conditions so manufacturers are getting interested," said Jon Almer, a co-author on the publication and scientists



A mechanical stress testing setup with a custom-built compact furnace and cooling system that mimic extreme operating conditions on turbine engines at the Advanced Photon Source at Argonne National Laboratory. Photo credit: DLR.

at the APS. "I would expect the APS to remain the only place in the world with these capabilities for at least the next couple of years, if not longer." Already the military and two Fortune 500 companies have shown interest in conducting similar future experiments at the APS.

A proposed upgrade of the APS to become the nation's brightest high-energy synchrotron would give industry even more options. A factor of 100 increases in brightness of the X-ray beam would enable the study of more types of coatings and increase sensitivity to the micro-structural evolution of defects. Added coherence in the X-rays would reveal smaller features in the defects, potentially from today's 200-micron feature to about a 200-nanometer feature. "Manufacturers have told us they would really appreciate that," Almer added.

In *Nature Communications*, the team outlined the first test of the system and reported previously unseen relationships between internal strains and thermo-mechanical operating conditions enabled by this novel experiment technique. In particular, specific operating conditions were identified which caused severe gradients, as well as undesired tensile strains in the coating layers. This previously unknown material behavior will be used to validate simulations of these operating conditions, to ensure safe operating windows are maintained. Furthermore, this information can be used to improve the deposition process during manufacturing, innovate coating materials, and allow for the use of coatings at higher temperatures, which could lead to wider adoption.

"The productive efforts of this collaboration bring high-temperature materials system testing to the next level," said John Okasinski, co-author and assistant physicist in Argonne's X-ray Science Division. "It will also facilitate unique insights into thermo mechanical states, particularly at the thermally grown oxide layer."

This work was funded by the National Science Foundation and the German Science Foundation. The APS is a Department of Energy Office of Science User Facility.

Taking the Measure of a Manufacturing Training Program

ITAMCO, an open gearing and precision machining services company in North Central Indiana, has taken a proactive stance against the lack of skilled manufacturing workers. ITAMCO founded a manufacturing training program for high school students that has become a success story for ITAMCO, the community and the students. The following press release outlines ITAMCO's continuing commitment to the program.

Plymouth, Indiana – ITAMCO (Indiana Technology and Manufacturing Companies) has donated a Zeiss Coordinate Measuring Machine (CMM) to the Precision Tool Manufacturing Training Program for high school students. The donation was announced at the 2014 International Technology Manufacturing show in Chicago. The new machine is evidence of ITAMCO's continuing support for the program that Mark Neidig, Purchasing Manager at ITAMCO, proposed to the Plymouth School Corporation superintendent in 2013.

The new machine will be added to the inventory of precision machining tools housed in the ITAMCO Manufacturing Center on the Plymouth High School's campus in North Central Indiana. In addition to ITAMCO's $100,000 initial donation and ongoing technical assistance, the North Central Area Vocational Cooperative (NCAVC) and Ivy Tech are active contributors. NCAVC contributed funds to purchase equipment and the program's trainer is an Ivy Tech employee. Students receive high school credits and Ivy Tech college credits.

ITAMCO provides open gearing and precision machining services and, like many manufacturers, needs highly skilled employees to operate their technologically advanced CNC equipment. Mr. Neidig said that he initiated the program because the ITAMCO team wants to encourage high school students to enter rewarding careers in manufacturing. "We need to keep the USA at the forefront of innovative manufacturing, but we obviously have selfish motivations as well. We need skilled workers in our own facilities," said Mr. Neidig.

The ITAMCO staff donated a Zeiss DuraMax CMM because it's a world-class machine like the Zeiss CMM machines they use on their own shop floor. The DuraMax replaces the limitations of manual measuring tools with CNC accuracy and flexibility. "Our facility is better equipped than a typical machine shop and we want participants in the training program to be prepared to work on a plant floor like ours," said Mr. Neidig. Zeiss generously discounted the price of the machine, contributed 12 educational licenses for their Calypso software for the DuraMax, and provided training for the manufacturing center's instructor. The Calypso software enables users to create a measuring plan without programming code or text editing.

After only one year of operation, the training program has success stories. Thirteen students have taken Precision Machining I and four were seniors. Three of these seniors are now working at ITAMCO after graduation and one of the ITAMCO employees is continuing his education at Ivy Tech. The fourth student is also working for a local manufacturer. "The companies were pleased with our students' training because they were prepared to work on the shop floor, said Scott Kaser, the instructor for the Precision Tool Manufacturing Training Program and a certified CNC Machinist with over 25 years experience as a machinist and trainer. "I was just like these kids. I didn't want to go to college but I wanted a good paying job. I like working with them and I enjoy our partnerships with local companies that want to hire them," he added.

About ITAMCO
Since 1955, ITAMCO has provided open gearing and precision machining services to heavy-duty industries including energy, mining, marine, and aviation. Learn more about ITAMCO at www.itamco.com or call (574) 936-2112.

Students from the Metalworking I class at the Precision Tool Manufacturing Training Program. From left to right: Trevor Roberts, Tanner Virgil, Luke Neidlinger, Blake Carbaugh, AJ Avery and William Penrod.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Eleventh International Conference on Barkhaussen Noise and Micromagnetic Testing

THE INTERNATIONAL CONFERENCE on Barkhausen Noise and Micromagnetic Testing (ICBM) is pleased to announce that the next ICBM Conference—the 11th since their start in 1998—will be held on June 18-21, 2015 in Aydin, Kusadasi, Turkey.

The Conference will be held in conjunction with the 8th International Conference and Exhibition on Design and Production of Machines and Dies/Molds (DIEMOLD). The Conference is organized in cooperation with the Metal Forming Center of Excellence and Atilim University from Ankara, Turkey.

The ICBM Organization is honored to be included within the DIEMOLD 2015 Conference, which is to be held at Kusadasi Pine Bay Resort Hotel. The ICBM special sessions are preliminary planned to be held on June 19–20, 2015. Both ICBM and DIEMOLD participants can attend all sessions and events including opening cocktail, coffee breaks, dinners, lunches and gala dinners.

For more information on the venue and arrangements, see the DIEMOLD Conference at www.diemold.net.

About Barkausen Noise and Micromagnetic Testing

Professor Heinrich Barkhausen discovered in 1919 the phenomenon of Magnetic Barkhausen Noise, which is a faint noise-like signal, generated by moving magnetic domain walls. While this discovery was initially of scientific interest, it is only in more recent times (since 1980s) that it has found a rapid rise in academic and industrial interest through the discovery that Barkhausen noise can be used to non-destructively characterise a range of material properties important in engineering components.

Magnetic Barkhausen noise has now developed into a sophisticated quality control tool that is used in a range of industries such as automotive and aerospace and it is actively being researched in a number of academic establishments around the world.

by Mark Hayes | Institute of Spring Technology | ist@ist.org.uk

Cautionary Tale: Shot Peen Stress Relief

The following article is reprinted with permission from *Springs* magazine, Summer 2014

THE MANAGER of a spring manufacturing company recently asked why his company always gave compression springs a stress relief heat treatment after shot peening, except when the springs are warm prestressed or painted after peening. Once the effect of this process had been explained, and confirmation had been given that the heating for warm prestressing or paint curing (at 180-200°C) did the same job as the stress relief, the manager then wanted a technical explanation of exactly how the stress relief worked.

In a similar vein, the manager of a shot peening company expressed surprise when he heard that springs should be stress relieved after peening. His company peened many aircraft components, and never applied any heat after peening for fear of a reduction in the residual compressive stress achieved during peening. This is a subject the company knew a lot about because they are obliged to measure residual stress profiles achieved by their peening process. Indeed, once it had been explained that IST had data showing that spring fatigue performance was not reduced when a temperature of 220°C was used, the company measured the residual compressive stress at 45° to the inside surface of compression springs, and found, to their surprise, how little the residual stress was reduced by this stress relief heat treatment.

A novelty for this column is the inclusion of test results specifically generated to confirm the benefits of post-peening stress relief of springs. Compression springs made from 1.5mm diameter pre-hardened and tempered silicon chromium wire were stress relief heat treated at 400°C after coiling, and then shot peened with 0.3mm steel shot. Half of the batch of springs were given a stress relief at 220°C after peening, and half were not. The two batches were load tested to quantify the length at which significant load was lost, and the reduction in free length due to prestressing to the closed length (load ~50% greater than τ_c.)

These results clearly show that the compression springs will take a significant set on first application of load if they are not stress relieved after peening. The explanation for this is that the shot peening generates numerous dislocations within the material microstructure, which contribute to the residual compressive stress at the spring surface. However, these dislocations are mobile and some will "run away" from the surface when the spring is loaded. If the springs are heat treated at between 200 and 250°C, the mobile dislocations become decorated with strain age hardening precipitates, which render them much less mobile. That is a rather more technical explanation than is usually given in this column, but a spring manufacturer asked the question and there is no simpler answer!

The moral of this cautionary tale is that observations made by spring manufacturers about the behavior of springs may be fully explained by the leading experts in this field of technology, and at a simpler level, the stress relief heat treatment after peening is strongly recommended.

LTHT (°C)	Length at loss of 0.5N load (mm)	Shortening after prestress to 180N (mm)	Spring Rate (N/mm)	Outside Diameter (mm)	Free Length (mm)
400	15.5	0.52	1.50	19.20	65.5
400 + P	36	2.00	1.46	19.33	65.5
400 + P+ L	16	0.55	1.46	19.33	65.5

Figure 1. Results for silicon chromium springs. P = shot peened, P+L = peened then a low temperature heat treatment (LTHT) at 220°C.