METAL IMPROVEMENT
WORLD

News About Today's Metal Treatment Technologies

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VOLUME 2

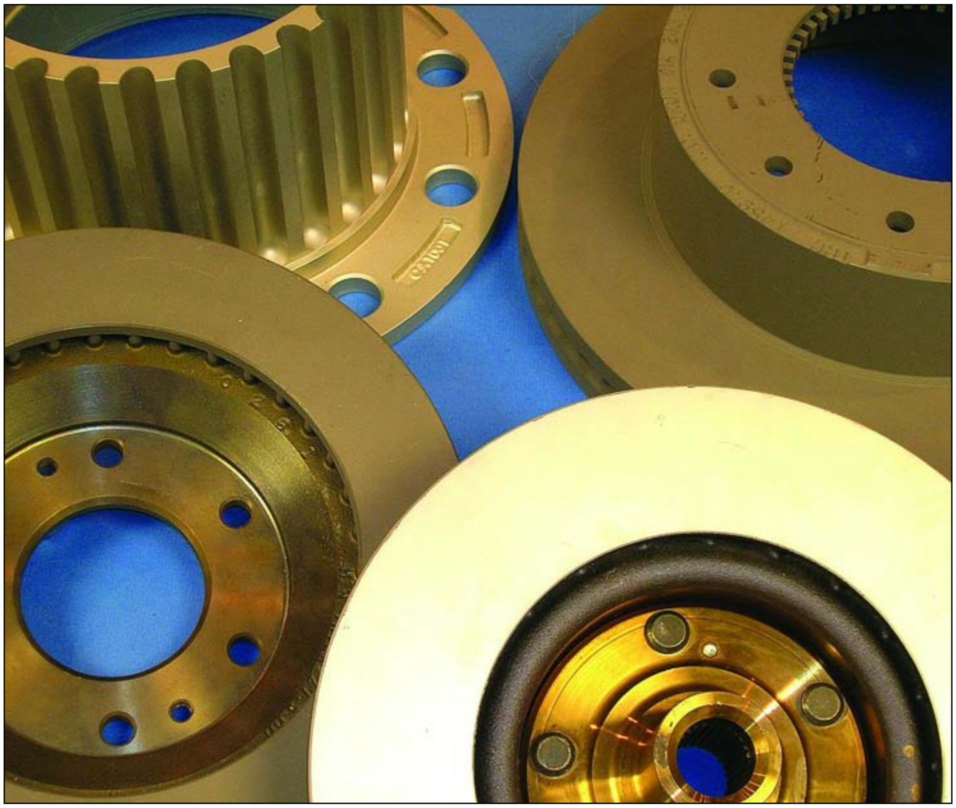
In This Issue

Two Specialty Coating Facilities Join MIC

Metal Improvement Company (MIC) has acquired two coating facilities from Diversified Coatings, Inc. of Ridgway, PA that specialize in the application of high performance coatings primarily for automotive industry components.

The two new MIC facilities are located in Fremont, IN and Ingersoll, Ontario. The 72,000-square-foot Fremont facility previously operated as Allegheny Coatings - Fremont, and the 44,000-square-foot Ingersoll facility operated as Diversified Coatings Canada. Both facilities utilize highly automated spray coating lines to apply high performance coatings for corrosion, oxidation, lubricity and cosmetic applications. Although their primary business is the spray application of galvanic high performance coatings for automotive industry brake rotors, ball studs and stampings, these facilities also provide application services to the farm equipment, trailer, military, marine and construction equipment industries. Among the coating technologies applied are:

- Zinc rich coating systems (Dacromet®/ Geomet®, Magni, Delta, Zintek)
- Dry film lubricants (Everlube®)
- Aluminum rich coatings (SermaGard®)
- Powder coatings
- Chrome free corrosion resistant coatings
- Powdered metal porosity sealing coatings.



The newly acquired facilities specialize in the spray application of galvanic high performance coatings for automotive industry components.

The acquisition of these facilities expands MIC's coating services business, which includes six E/M Coating Services facilities in the United States and one in the United Kingdom. E/M Coating Services is the largest applicator of solid film lubricant (SFL) coatings in North America. SFL coatings are effective in a broad range of applications whenever conventional wet lubricants provide insufficient protection due to high temperatures, extreme loads, corrosion, wear, chemical corrosion and other adverse operating conditions. The SFL coatings applied by the E/M Coating Services network are complementary to the corrosion resistant coatings that are currently applied by the Fremont and Ingersoll facilities. ■

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Use of Laser Peening to Enhance Fatigue Life of Aircraft Structures and Turbine Engine Components

Lloyd A. Hackel, C. Brent Dane, Fritz Harris, Jon Rankin, and Chanh Truong - Metal Improvement Company

Introduction

In critical applications, fabricated metal components are often required to carry high tensile stress loads, reside in corrosive environments and can be subjected to cyclic loading. These factors will all contribute to potential fatigue or corrosion failure. Surface treatments such as shot peening and surface rolling have long been used to retard fatigue crack formation and growth and consequently to mitigate failures. These processes are effective but can be limited in the benefit obtained due to the limited depth of compressive stress that is achieved by the process. Laser peening, a new production technology, can create compressive stresses that are four times or more deep than those attainable from shot peening and in a very controlled fashion. Consequently, components that are laser peened are able to achieve greater fatigue strength and greater lifetimes and significantly enhanced performance in corrosive environments.

Acceptance of any new process by engineering authorities is key to bringing the process into the mainstream of engineering design. Laser peening technology is now available on a reliable commercial basis and has been recognized by the SAE specification as a process (ASM 2546). Laser peening processing facilities have been certified as FAA approved workstations for treating jet engine components and have attained ISO 9001 certification.

The Laser Peening Process

The basic physics of laser peening, known for some 25 years[1,2], is shown in **Figure 1**. A roughly 25 J at 25 ns output beam from a Nd:glass laser is directed at a workpiece in an area where it is desired to induce residual compressive stress. The area to be peened is covered with a tape or coating, which acts as an absorbing ablative layer for the laser light and simultaneously as a thermal insulating layer. A 1-mm-thick stream of water is made to flow over the ablative layer and act as an inertial pressure-confining layer for the plasma that is created. The laser light passes through the transparent water layer and vaporizes the ablative surface to form a plasma rapidly that is highly absorbent for the rest of the laser pulse. This plasma is confined by the inertia of the water layer and attains a pressure in the range of 100 k bar. The spot size for an individual laser peening impact is a square in the range of 3-10 mm on a side. The size of the spot is adjusted to generate an overall pressure bubble that is slightly in excess of the yield strength of the material being peened (i.e. larger spots for aluminum and smaller for high strength steels).

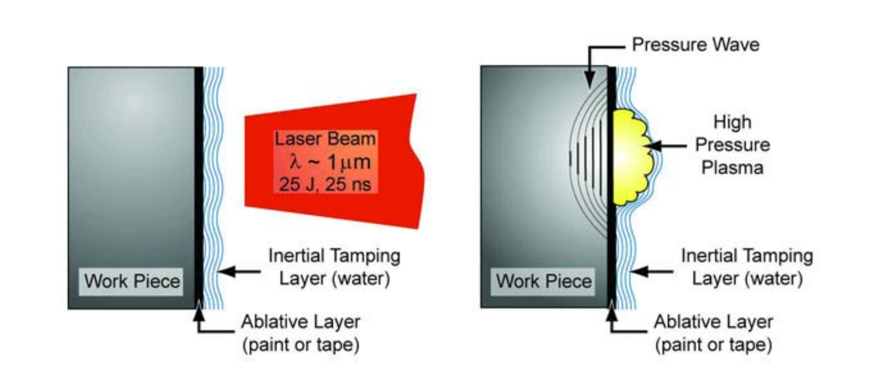

Figure 1. In the laser peening process, ablation of a sacrificial layer at the surface of the part creates a high-pressure plasma and consequent shock wave that results in a deep compressive stress in the workpiece.

This laser beam spot creates a planar shock wave that plastically strains the underlying material leaving behind a layer of residual compressive stress that is four or more times deeper than that attainable from shot peening. In this high strain rate process, the shock wave and thus the plastic straining occurs at roughly the same rate at which dislocations are formed. This means that cross-slip and networks associated with cold work are minimized while deep, intensive compressive stress is still achieved. Laser peening achieves the benefits of deep compressive stress without the detriment of high levels of cold work. By precisely controlling the laser parameters, the intensity and depth of the applied residual stress can also be controlled.

Application to High Performance Steels

Metal Improvement Company has applied laser peening to 300M steel to improve its fatigue performance, increase damage tolerance and reduce the rate of stress corrosion cracking. 300M is a low alloy, vacuum melted steel of very high strength — basically a modified AISI 4340 steel with silicon, vanadium and slightly greater carbon and molybdenum content than 4340. Applications for 300M steel are those that require strength in the 290 - 300 ksi range, such as aircraft landing gear, high strength bolts and airframe parts.

In this work, we compared the performance of 300M "as machined" and shot peened coupons from other studies[3] against the performance of equivalent 300M coupons that were laser peened by MIC. In the experiments, separate evaluations for each of the treatments were done respectively for smooth coupons, for coupons with a 0.020-inch-deep notch and for coupons alternately exposed to a salt bath and then fatigue tested.

An important feature of laser peening is the ability to place deep levels of compressive stress and to specify and highly control the intensity and depth of that applied stress. **Figure 2** is a plot of compressive stress for various laser peening parameters in 300M. The stress was determined by a strain measurement technique called slitting.[4,5] The results show how the compressive stress can be precisely varied as the intensity and number of layers of laser peening are varied. The first number identifying each entry represents the laser fluence in GW/cm2, delivered to target. It represents how intense the intensity of the peening. The second number represents the laser pulse duration in nanoseconds. In this work the pulse was kept at 18 ns for all tests. Shorter pulses than this would tend to impart a shallower stress and longer pulses a deeper stress. The third number identifying each entry represents the number of layers of laser peening coverage. A "3" represents three separate layers of peening (or 300% coverage.)

It is important to recognize in this example that laser peening imparts compressive stress only. The tensile stress seen in the figure to the right for each sample is the result of the sample being thin enough (0.5 inches) that it can and did appreciably bend due to the applied stress. A more correct representation of the stress that would have been measured in an infinitely thick sample, termed the eigenstress, is determined by fitting a straight line to the right hand tensile portion of each curve, so as to calculate the linearly varying stress associated with bending[6]. Sample bending effectively releases stress from the thin coupon, stress that would otherwise be developed in a thicker component. Because stresses superimpose, the bending stress can be subtracted from the measured stress to find the true or eigenstress imparted to the block.

Figure 3 shows an example of the effectiveness of surface stress applied by shot peening or laser peening to enhance the fatigue strength or fatigue lifetime of smooth undamaged samples under cyclic loading. The test here is done using 4-pt bend bars with R=0.1 and loading in the range of 130 ksi to 240 ksi. For these smooth samples, surface compressive stress and smooth surface condition are critically important to prevent crack initiation. However as soon as damage is introduced to the samples, performance is dramatically impacted by the depth of residual stress.

The fatigue benefits of laser peening can be even greater when the geometry of real components is considered. Geometric features and damage in service can result in locally increased stress, quantified as the Kt value, in the feature region. These stress risers negatively impact fatigue life and fatigue strength. With laser peening, the ability to apply an intense, deep compressive stress creates an even greater resistance to crack growth as compared to an untreated component. **Figure 4** shows the results of a very similar test except that the "as-machined" and laser peened samples are subjected to a 0.020-inch-deep notch cut in with an EDM wire simulating foreign object damage or to an alternate bath in a 3.5% salt (NaCl) solution during the fatigue testing simulating a corrosive environment. The fatigue strength of the "as-machined" coupons is dramatically reduced. In contrast, the laser peened sample, with deep compressive stress, still exhibits significant resistance to crack propagation and thus has only slightly reduced fatigue strength in the presence of the damage or corrosive environment.

Further evidence of the significance of deep residual stress is shown in **Figure 5**. Here, to the results presented in Figure 4, are contrasted the resistance of samples with shot peening to the 0.020-inch notch or the corro-

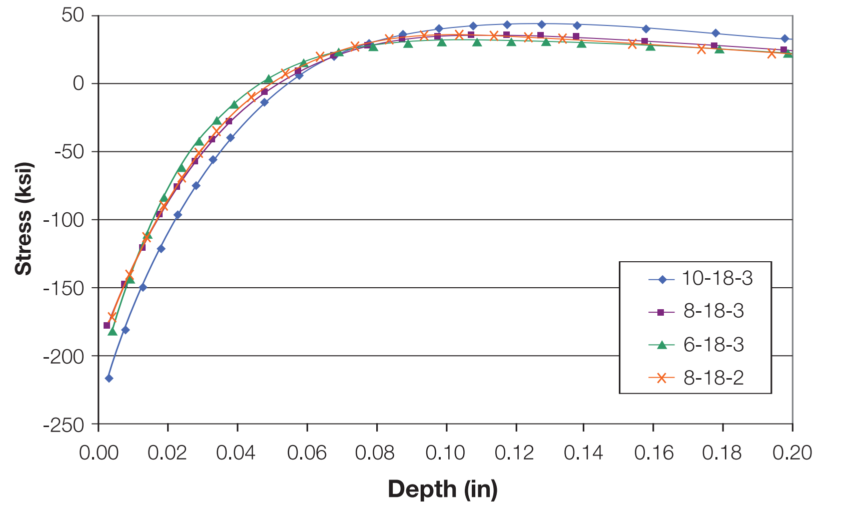

Figure 2. Compressive stress developed by laser peening in 300M in a 0.5-inch-thick sample not corrected for sample bending.

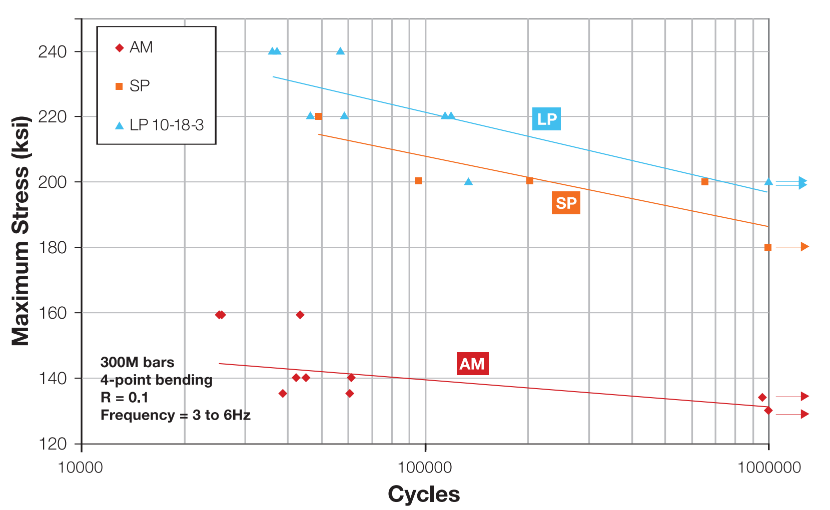

Figure 3. Effect of laser and shot peening on the fatigue lifetime of 4-pt bend bars with Kt=1. Both treatments are highly effective in increasing the fatigue strength for this smooth surface case where surface stress is critical to prevent initiation.

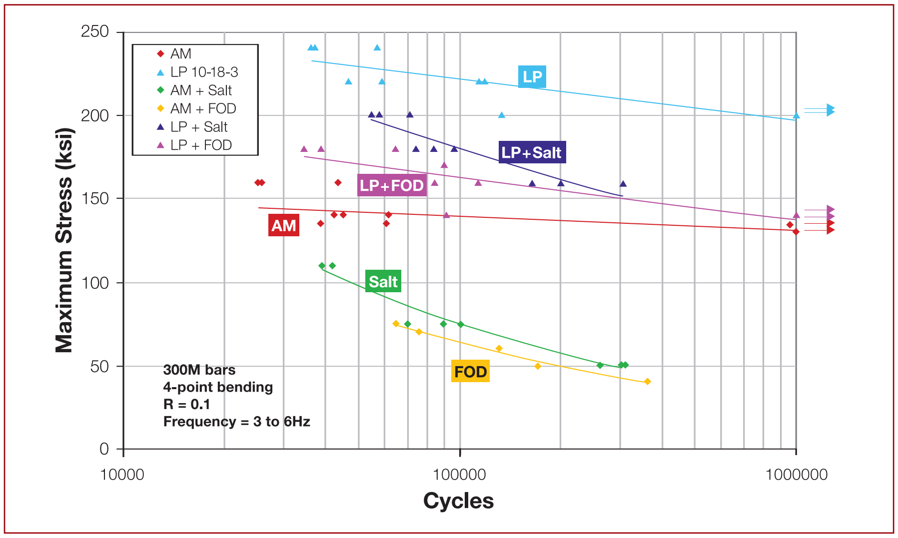

Figure 4. Stress-lifetime curve for laser peened and as machined samples damaged by a 0.020-inch notch cut into the high stress region of the sample using an EDM wire or corrosion simulated by alternate exposure to a 3.5% salt bath. The lack of surface compressive stresses results in rapid deterioration of the AM samples whereas the laser peened samples show more than 250% advantage in fatigue strength.

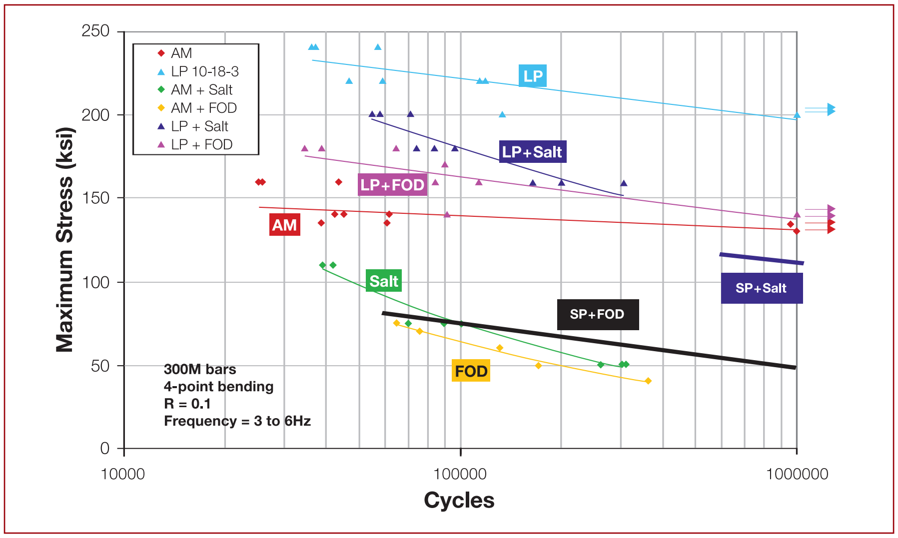

Figure 5. Deep level of residual stress generated by laser peening dramatically distinguishes it from shot peening in the presence of damage such as FOD or salt corrosion.

sive alternating salt bath. Shot peening typically imparts a compressive stress of 0.010 inch depth. With the notch damage being twice this depth, it has effectively cut through the compressive stress layer eliminating its effectiveness. The effect on corrosion is similar in the shot peening case. However, the laser peened samples have compression to 0.040 inches and deeper and thus resist crack growth much more effectively.

For a component to fail by stress corrosion cracking three conditions must be met:

1. The material must be susceptible to corrosion.
2. There must be a corrosive environment present.
3. There must be tensile stress in the crack area.

Eliminate any one of the three and stress corrosion cracking will not occur. In many cases, changing materials is not an option or is an expensive option because the material is usually chosen for particular attributes such as yield strength, ductility, etc. and is already employed and certified for other reasons on established aircraft. Components are required to operate in designated environments such as salt air, and thus the environment cannot be altered. Coatings may give initial protection but are susceptible to damage or cracking if they are permeable to the environment. Thus the best option for eliminating stress corrosion cracking is to remove the surface and near surface tensile stress. The deeper the compressive residual stress, the greater damage tolerance achieved. This is well accomplished with laser peening.

Laser Peening of Large Field Components and Systems

Laser peening was introduced to production in an in-house environment with a stationary beam and robots for handling components. In the initial processing, 1-meter-scale-length fan blades for commercial jet engines were picked up by a robot and systematically moved in front of a stationary laser beam allowing point by point treatment of the areas to be peened. However many applications of interest to the aerospace community will involve components and systems much too large to be moved and consequently these applications require the ability to move the laser beam over a stationary component. Additionally, components often need to be peened in the field, such as at a hanger, a shipyard or at a tank or pipe assembly yard, under conditions in which the setup will be temporary and the site remote. In order to accomplish both of these objectives a transportable laser system and a moveable beam delivery arm have been developed and demonstrated.

With a mobile laser peening system, the output of the laser generated in the trailer clean room is directed out of the trailer by using an optical telescope and into a laser peening chamber. Inside the laser peening chamber, two gimbaled mirrors operate in unison to reflect the laser beam and align it with the optics package mounted on the robot arm. The robot arm moves and points the focused laser beam over the full area of the part to be laser peened. **(Figure 6)**

The moveable beam enables large components, too big to be manipulated by a robot, to be laser peened. However, equally important for timely, cost effective application of laser peening, is the ability to transport a complete laser peening system to the field and rapidly set it up and operate it. **Figure 7** shows a laser peening system packaged in a fully transportable trailer that can be rapidly deployed to anywhere needed. It is fully self-contained, with transport storage space for the robotic beam manipulators and requires only 40 kW of electrical power to operate. If needed, a generator can be brought along to provide the electrical power.

An important aspect of the moveable beam and transportable peening system combination is that the laser system and controls can be set up, for example in the parking lot of a manufacturing facility or a hanger and the beam "piped" into the facility, hundreds of meters away, where the peening is to be done. The moveable beam robot is placed at the end of the beam pipeline at the peening site and this work area is shrouded in a light containing curtain such that other activities can continue as the peening work is being accomplished.

During the past four years, laser peening has made a major transition from that of a laboratory research technology into a highly reliable production tool with dedicated production facilities in the US and UK[7]. To date over 15,000 safety critical components have been laser peened and are in routine service on hundreds of wide body and small corporate sized jets. The facilities are approved as FAA/JAA Certified Work Stations for doing overhaul work and carry ISO 9001 certification for work on new production parts. The lasers have proven to be very reliable with availability exceeding 97% in 24-hour-per-day operation. The technology has matured to the point where it is an engineering tool both for new design and for overhaul.

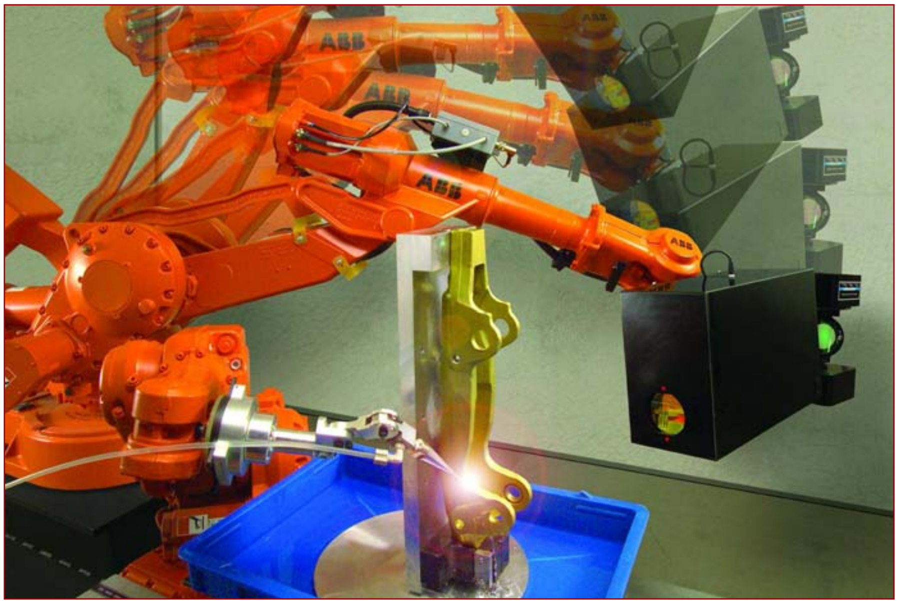

Figure 6. Moveable beam assembly comprising two electronically controlled, gimbaled mirrors and beam conditioning hardware allows movement of the peening laser beam over a stationary component such as an aircraft structure.

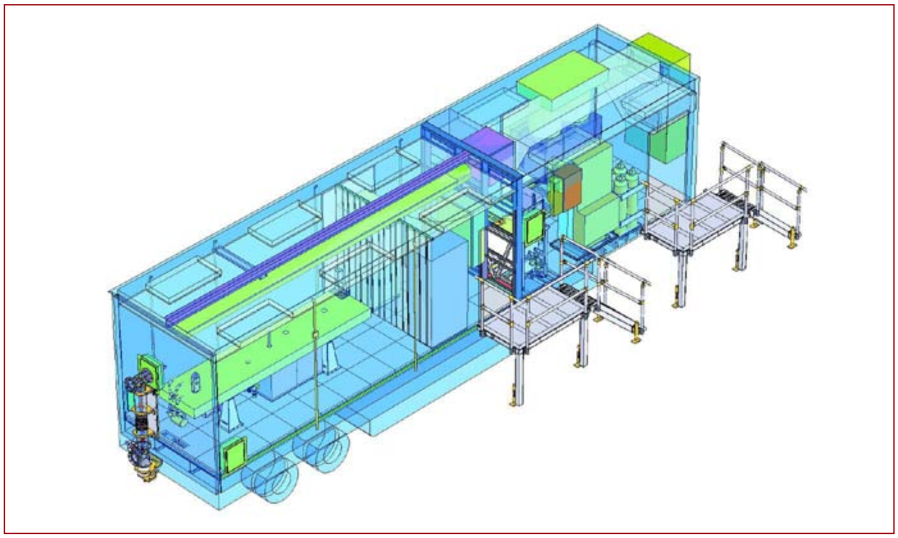

Figure 7. The laser peening system has been packaged into a transportable system for remote processing applications. Requiring only electrical power, a fully equipped peening system can be rapidly set up at field sites for overhaul and repair work.

Acknowledgments

Our development of laser peening technology benefited greatly from a Cooperative Research and Development Agreement between Metal Improvement Company and the Lawrence Livermore National Laboratory. We are indebted especially to Tania Zaleski, Jack Rybak and Hao Lin Chen. We also have a strong interaction on residual stress and fatigue with Professor Michael R. Hill of the University of California at Davis and his students. They performed the fatigue testing presented in this paper. ■

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Excerpted from a paper presented at the 9th Joint FAA/DoD/NASA Conference on Aging Aircraft, Atlanta, GA, March 6-9, 2006. Reprinted with permission.

Mobile Laser Peening Available for On-site Service

With its new Mobile Laser Peening Facility, MIC can now bring the benefits of this technology on-site to a customer's location for the treatment of large components that cannot otherwise be moved due to size, logistics or cost.

The Mobile Laser Peening Facility incorporates the use of a transportable laser system and a moveable arm that aims the laser beam. The Mobile Laser Peening Facility is ideal for treating components in the field, such as at an aircraft hanger, a shipyard or a tank or pipe assembly yard, under conditions where the setup will only be temporary.

The Mobile Laser Peening Facility contains a fully equipped peening system that can be set up at field sites in less than one week, then dis-assembled and made ready for transport to another site in approximately two days.

An important aspect of the moveable beam and transportable peening system combination is that the laser system and controls can be located several hundred feet away from the component to be laser peened. Then, the laser beam is "piped" into the facility to the location where the laser peening will be performed. The moveable beam robot is positioned at the end of the beam pipeline to direct the laser at the component to be peened.

Components of the Mobile Laser Peening Facility, which is contained within a 40-foot-long trailer, include:

- A temperature controlled Class 1000 clean room containing a 25-Joule Neodymium Glass Slab laser with interlocked laser safety system.
- A portable process chamber with moveable laser beam delivery system.
- An enclosed maintenance room with laser cooling equipment, HEPA filtration, humidity control system, electrical panels, Di-ionized water generation pad and air compressor.

The trailer includes everything needed for operating the laser and robot system. To operate on-site, the mobile facility only requires a three-phase high voltage connection and a house water connection. The electrical power distribution system covers both the laser and robot.

A fully equipped peening system can be rapidly set up at field sites for overhaul and repair work. Once it arrives on-site, MIC can set up the Mobile Laser Peening Facility in less than one week; it can be dis-assembled and made ready for transport to another site in approximately two days. The unit has dual voltage capability to enable operation throughout the world. ■

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HOT TOPICS....

News about MIC's Heat Treating Operations

Wichita, KS
The Wichita-West heat treating facility has increased its capabilities for hot straightening of precision aluminum components that become out of dimensional tolerance due to machining or annealing. MIC first heats the parts to appropriate precipitation hardening temperatures, and then manually straightens them while still hot. This mitigates any residual stresses that might be induced during the straightening process. The facility has been very successful in restoring the dimensional parameters of critical aerospace structural components (ribs, stringers, spars, etc.) for the F-18 and C-17. ■

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Roselle, NJ
The Roselle, NJ heat treating facility has added several new aerospace approvals as well as in-house capabilities to better service its customers.

- Boeing awarded the facility three new aerospace approvals relating to its capabilities in heat treating of alloy steels (BAC5617), carburizing of carbon and alloy steels (BAC5641) and pyrometry (BAC5621). In addition, Honeywell has approved the Roselle location for performing hardening and testing.
- The Roselle facility has also expanded its capabilities in the areas of vapor degreasing and austempering. A batch vapor degreasing unit with a 20-inch x 24-inch chamber was added to meet the requirements of clean products for customers in the medical, dental and surgical instrument industries. In addition, to reduce component distortion a batch austempering unit with chamber dimensions of 36 inches x 36 inches was also installed. ■

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Bensalem Facility Adds Sulfuric Acid Anodizing Capability

The MIC metal finishing facility in Bensalem, PA has expanded its anodizing capabilities with the addition of a sulfuric acid anodizing (SAA) line that utilizes tanks measuring 40 feet long by 5 feet wide by 12 feet deep—the largest SAA non-captive tanks on the U.S. East Coast.

The new line is ideal for processing large structures that were previously hard to sulfuric acid anodize because of their size. Manufacturers of large structures, such as aluminum bleachers, platforms, handrails, complicated weldments and architectural panels can save production costs and time. The new SAA line enables them to sulfuric acid anodize large parts in their assembled condition instead of anodizing the individual small parts and then assembling afterwards, which increases the risk of scratching and damage.

MIC designed its new SAA line and existing chromic acid anodizing line to handle large as well as small metal finishing projects. Flexible racking systems, combined with this processing equipment, enable the pretreatment, anodizing and coating of parts ranging in size from 38 feet to smaller than one inch in the same metal finishing facility.

For phosphoric acid anodizing (PAA), our fully automated, plc-controlled PAA line can handle parts measuring nine feet long by four feet wide.

A dedicated clean room with adhesive priming capability and curing oven is located only a short distance from any of these anodizing lines.

MIC s sulfuric acid anodizing line in Bensalem, PA features tanks measuring 40 feet long by 5 feet wide by 12 feet deep the largest SAA non-captive tanks on the U.S. East Coast.

CUSTOMER COMMENTS

June 6, 2006

Metal Improvement
3434 State Road
Bensalem, PA 19020

Recently your company anodized approximately 570 ft. of aluminum guardrails for us. American Customs Fabricators has been fabricating aluminum railing for over 20 years, and this was by far the best anodizing job we ve ever seen. Due to the engineering on this project we were forced to build these railings using 6061 T6 Sch 80 pipe. Your anodizing looked better than anodizing by other shops on 6063 pipe.

Keep up the good work. You are now the anodizing source for all of our work.

Sincerely,

Robert C. Schinder
American Custom Fabricators
President

MIC's Bensalem facility offers the following aluminum chemical surface treatments:

- Phosphoric Acid Anodizing per BAC 5555, SS8482 and ASTM 3933-98
- Sulfuric Acid Anodizing per MIL-A-8625 TYPE II
- Chromic Acid Anodizing per MIL-A-8625 Type 1, BAC 5019, MPS 160-010, PPS32.01, DPS11.01 and SS8483
- Alodine Chemical Conversion Coating per MIL-C-5541, BAC 5719, MPS 160-20, CSFS027, PPS32.01, MIL-C-81706 and SS8486

In addition, the Bensalem facility has approvals to apply Kynar® 500, powder coatings and coatings from Everlube® Products, DuPont®, Solvay-Solexis and Valspar on parts up to 40 feet long.

The Bensalem metal finishing facility is Nadcap approved for chromic and phosphoric acid anodizing, Alodine, passivation, priming, painting and fluorescent penetrant inspection. ■

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MIC Enhances Web Site as a Customer Resource

Customers can now access and download data sheets and technical articles relating to MIC's core technologies of shot peening, laser peening, heat treating and specialty coatings via the MIC Web site.

This includes the ninth edition of the company's *Shot Peening Applications Guide*, which is known in the industry as the "MIC Green Book". MIC's *Shot Peening Applications Guide* is a comprehensive technical resource on shot peening and covers the process' theory, response to metals and effectiveness in various applications. The 64-page publication is available in four-color hard copy format, or you can download the entire manual or select chapters of interest in PDF format through the company's Web site.

Visitors to the MIC Web site also can subscribe to and/or download the *Metal Improvement World* newsletter. To visit the document download section of the MIC Web site, go to www.metalimprovement.com/joinnow.php ■

E/M Coating Services Facility Earns ISO/TS Registration

E/M COATING SERVICES

The E/M Coating Services Team proudly displays its new ISO/TS Registration.

The E/M Coating Services facility near Detroit, MI has achieved ISO/TS 16949:2002 registration—the highest level of quality approval available to companies performing work for the automotive industry. The registration is a testament to the facility's production and quality departments.

The facility specializes in applying coatings that provide solid film lubrication, chemical resistance and high temperature protection as well as other performance enhancing properties. In-house capabilities include robotic electrostatic spray and automated dip/spin coating equipment, the application of pretreatments and testing and analysis services. ■

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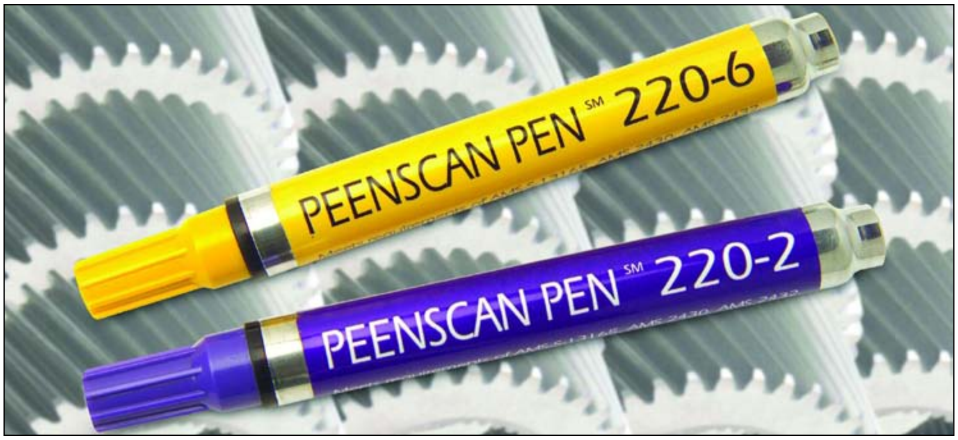
Peenscan Pen[SM] Helps Measure Shot Peening Coverage



MIC has introduced the Peenscan Pen, a new product for the shot peening industry that greatly facilitates quality control of the shot peening process.

The Peenscan Pen provides a convenient method for applying a thin coating of fluorescent tracer fluid to very specific areas of a part without the need for masking. The tracer fluid can be utilized during initial engineering set-up of a part for shot peening as well as for monitoring critical areas (gear teeth, etc.) during production shot peening. Use of fluorescent tracer fluid is a practical way to measure shot peening coverage in terms of amount and uniformity by monitoring the degree of removal of a fluorescent dye after shot peening.

The Peenscan Pen is available with two different fluorescent fluids. Selection of the appropriate Peenscan Pen is dependent on the hardness of the metal and the intensity of the shot peening process. Many aerospace, automotive and industrial manufacturers have approved the Peenscan process.

The Peenscan Pen is available for purchase directly from MIC, as well as from Electronics, Incorporated in North America and Nako-M-Link in Singapore.

To learn more about the Peenscan Pen, go to www.metalimprovement.com/peenscan_pen.php ■

Accredited Nadcap

MIC Facilities Earn Nadcap Approvals

The Metal Improvement Company facility in Bayonne, France successfully completed its Nadcap accreditation audit for shot peening and glass bead peening with automatic and computer controlled machines. The Nadcap audit verified processes utilized on components for Airbus, Boeing, General Electric, Messier Dowty and Turbeméca. ■

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The three MIC heat treatment facilities in Wichita, KS successfully completed their Nadcap reaccreditation audits:

- The West Street facility, which specializes in heat treatment and straightening of aluminum aerospace structural components, maintained its Nadcap approval for heat treatment of aluminum alloys;
- The McLean Boulevard facility, which specializes in performing carburizing, carbonitriding, and neutral hardening processes, maintained its Nadcap approval for heat treatment of ferrous-based materials; and
- The Ida Street facility, which specializes in induction hardening, maintained its Nadcap approval for vacuum heat treating.

In addition, all three facilities maintained their accreditation for metallography and material hardness testing as part of their full service metallurgical testing capabilities. ■

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METAL IMPROVEMENT WORLD
is published by Metal Improvement Company
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METAL IMPROVEMENT WORLD

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- ❑ Update my information.
- ❑ Delete me from the mailing list.

❑ I'd like to receive *Metal Improvement World* electronically.

Please provide the following information:

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Company: ______________________

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