Winter 2008

The Shot Peener

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Volume 22, Issue 1

Putting Turbulence to Work

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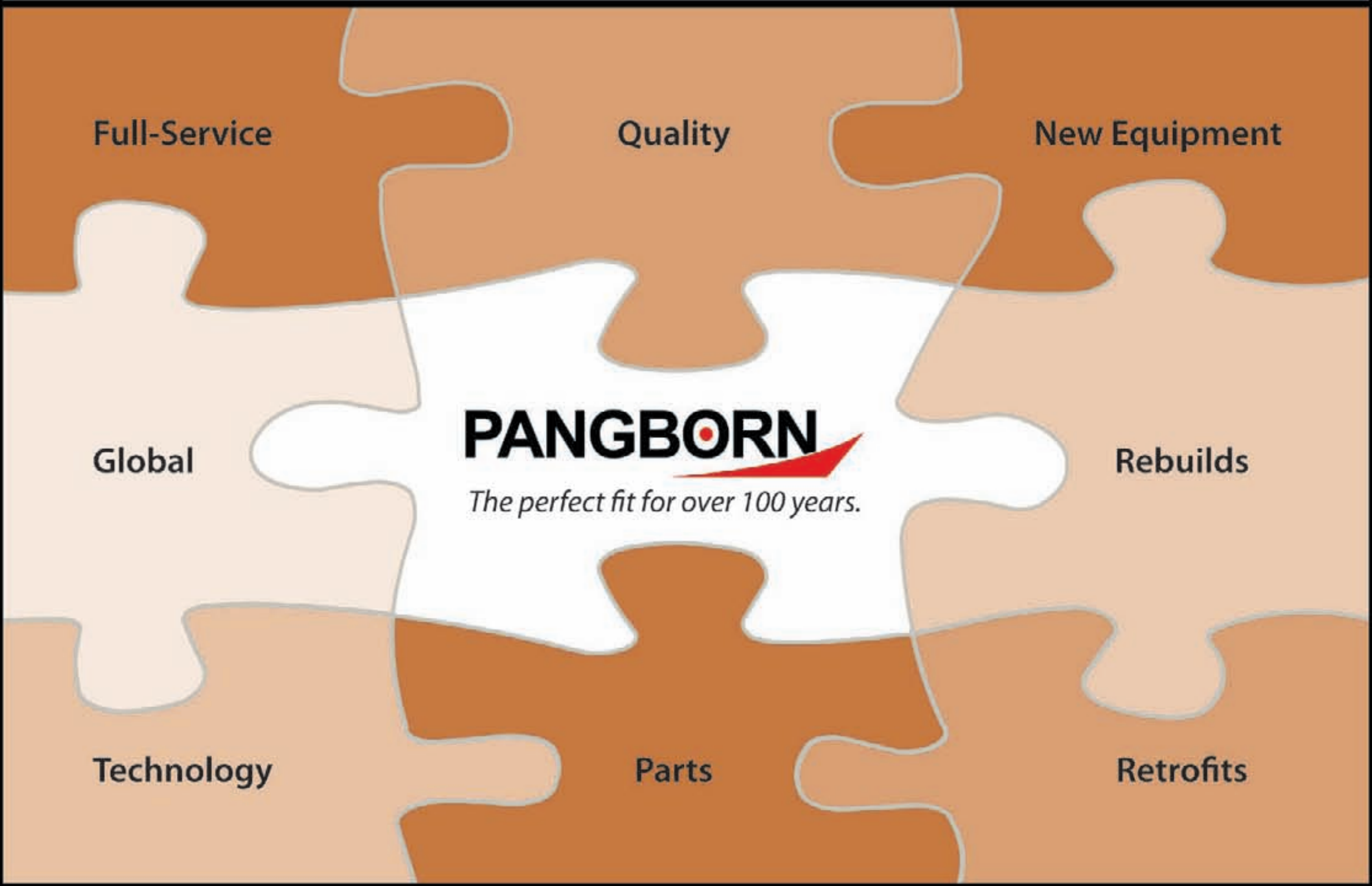

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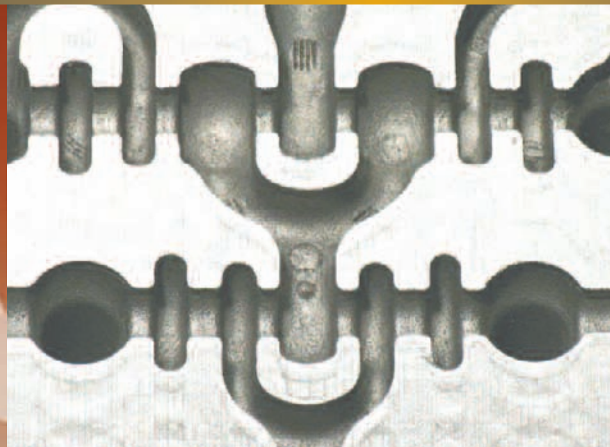

Cover Story

The Shot Peener (ISSN 1069-2010), in print since 1986, is a quarterly publication from Electronics Incorporated with a circulation of over 5,400 subscribers in 85 countries. It is dedicated to raising the awareness and appreciation for the shot peening and abrasive blast cleaning industries.

Contributions to The Shot Peener are always welcome including the announcements of seminars, application notes, and press releases on new products and services. However, while it is our goal to include all newsworthy information in The Shot Peener, we are able to use these items only as space allows and we cannot guarantee their placement in the magazine. Inclusion of articles in The Shot Peener does not indicate that The Shot Peener management endorses, recommends, or disapproves of the use of any particular commercial products or process, or that The Shot Peener endorses or concurs with the views expressed in articles contributed by our readers.

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The Shot Peener

Putting Turbulence to Work

Here's one of those wish-I'd-thought-of-it-first products that turns a liability into an asset. Steven Carpenter, an engineer with extensive experience in the foundry industry and an owner and partner at Grand Northern Products, has developed a process that puts turbulence to work—cleaning difficult-to-reach passages and highly-cored and deep components. "When I worked in foundries, first as a chief engineer and then as a plant manager, we found a common problem when cleaning interior passages, especially small I.D.s with long and/or irregular sections," said Mr. Carpenter. "In an effort to create turbulence that could be controlled, we tried introducing blast streams from opposing ends with some amazing results," he added.

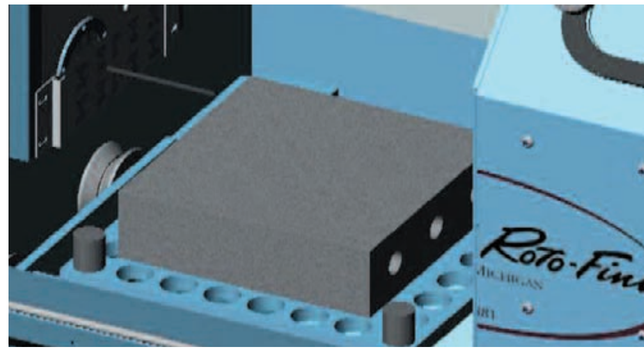
Mr. Carpenter developed the process until it was ideal for working internal features. In simple terms, the process uses two (2) or more opposing blast nozzles to impart reflective random energy to the blasting media at a chosen area. The process is capable of aggressively removing internal burrs, burned on/in sand, and leftover mold and core materials. "With a conventional lance, much energy is lost because the abrasive is forced to turn an abrupt corner at the nozzle tip which decelerates the material. However, two opposing nozzles create a mushroom effect and gives the added benefit of a 360˚ pattern, if desired," he explained. "We also proved that the nozzles do not have to be opposing in our process. This is advantageous where the part configurations don't allow opposing nozzles such as water jacket passages and oil galleries in engine blocks and turbo charger housings," he said.

Mr. Carpenter patented the process and has sold the marketing rights to Hammond Roto-Finish. Hammond Roto-Finish incorporated the process into a reciprocating blast system called Recipro-Blast™.

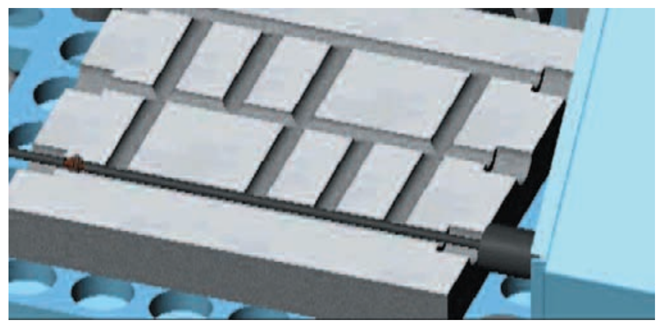
Hammond Roto-Finish has several of the systems in operation and is marketing the process to manufacturers of hydraulic/pneumatic manifolds, valve/fitting bodies, and transmission components. With Recipro-Blast, customers can address internal conditions inexpensively and effectively. "One of our customers is enjoying a significant savings in cleaning costs. Recipro-Blast replaced labor-intensive hand-cleaning, molten salt cleaning, and rotary brushes. The equipment paid for itself in a few months," said Mr. Carpenter.

Hammond Roto-Finish is finalizing a peening system based on controlling turbulence. Currently, most peening work in internal areas utilizes lances with some type of angle-hole configuration. A controlled-turbulence system will have greatly increased flow levels and a more favorable angle of impingement, thereby increasing peening efficiency. A specific application is for a springs manufacturer. Recripro-Blast works well for this customer because it eliminates the over-peening of the O.D. while achieving the desired results on the I.D.

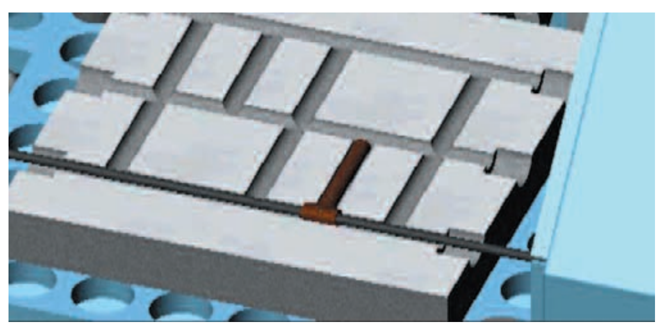
For more information on the Recipro-Blast, contact Steve Carpenter at Grand Northern Products:
Telephone: (616) 437-7154 or (800) 968-1811
Email: scarpenter@grandnorthern.com



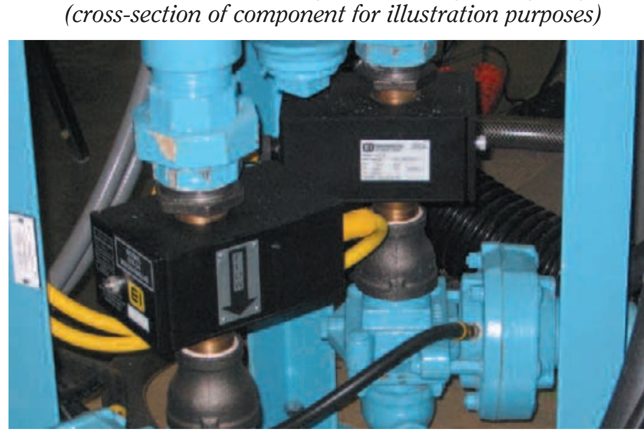
A component in the machine



Opposing nozzles create 360˚ blast pattern (cross-section of component for illustration purposes)



Blast pattern flows through intersecting passageways (cross-section of component for illustration purposes)



Blast media is controlled by magnetic flow valves

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PUTTING TURBULENCE TO WORK
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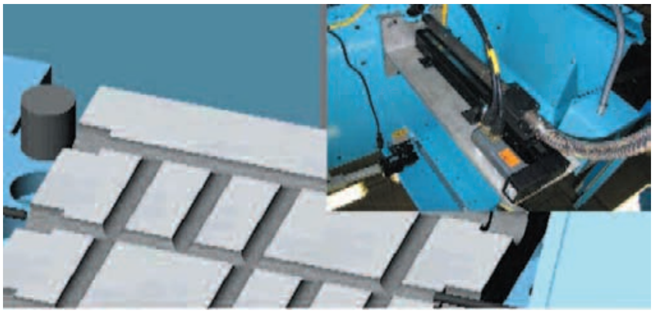
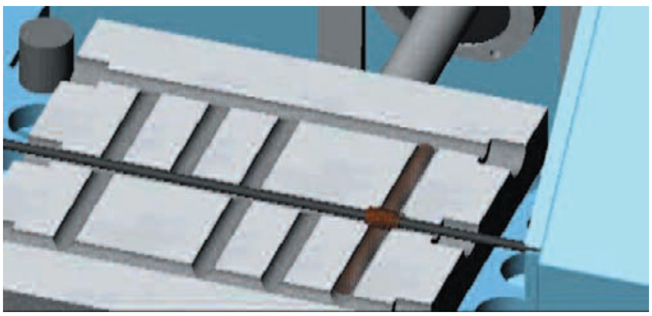
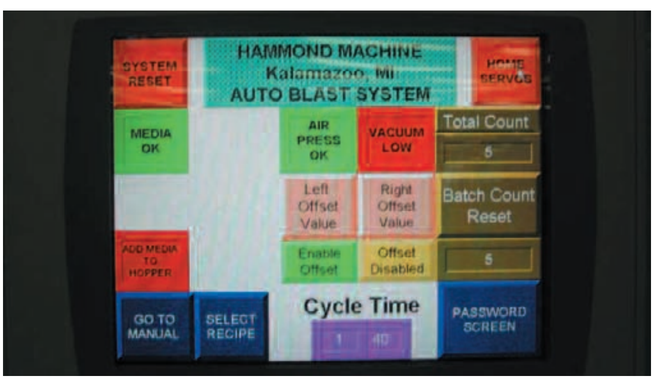


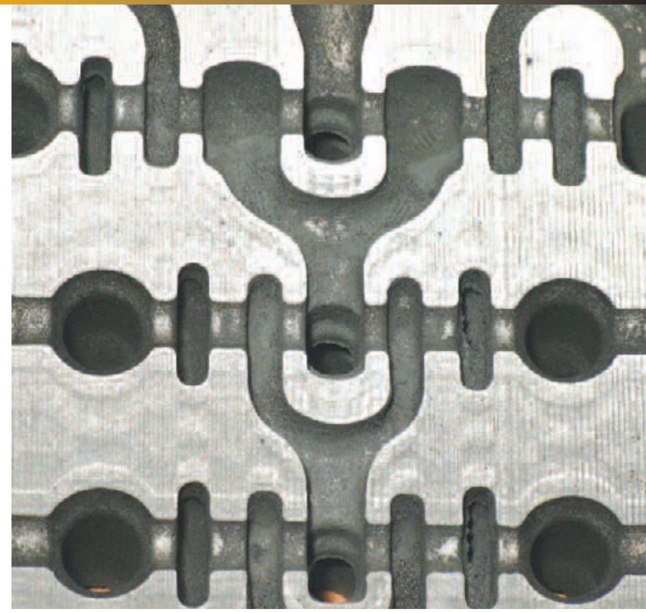
Servo-controlled nozzles and part movement (cross-section of component for illustration purposes)



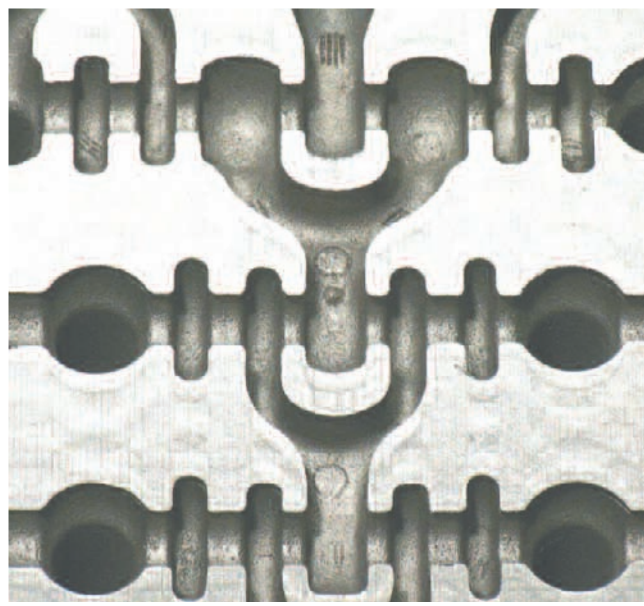
Servos can be programmed for many different parts (cross-section of component for illustration purposes)



System is controlled with easy-to-use touch screen



An hydraulic valve casting is cut in half to show the typical condition of a valve before cleaning



An hydraulic valve casting cut in half after going through the Recipro-Blast process. Note the casting definition of this part. "People have been so amazed by the results that they claim that we cut apart the components, blast clean them, and put them back together," said Steve Carpenter.

The Reciprocating Blast System

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A leading international distributor of surface enhancement technology located in Grand Rapids, Michigan, Grand Nothern Products specializes in equipment, supplies, processes, systems engineering, and production services to optimize finishing operations.

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About Hamond Roto-Finish

For over 120 years, Hammond Roto-Finish of Kalamazoo, Michigan has provided finishing solutions for automotive, aircraft, aerospace, medical instruments, implants, sporting goods, decorative hardware, jewelry, musical instruments, household appliance, plumbing and firearms industries.

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Shot Peening of Springs—a Case Study

John Cammett

Acknowledgments: The investigation that formed the basis for this article was instigated by the author in cooperation with four organizations that participated in experimental efforts as follows: the leaf spring manufacturer (leaf spring peening and fatigue testing), Electronics Inc. (media inspections), Lambda Research Inc. (residual stress measurements, metallography and microscopy) and Progressive Technologies (experimental peening trials). The contributions of all involved are highly valued and appreciated by the author. Additionally, the author acknowledges the combined efforts of Dave Barkley and Kathy Levy, with The Shot Peener magazine, to enhance the figures and graphs of the article.

Introduction

This article presents the initial findings from a peening optimization study in which improvements in peening processing and the durability of leaf springs were the ultimate aims. The project has not been completed, but there are valuable lessons already and these are highlighted in this article.

The leaf spring material was AISI 5160 steel, a nominally 1% Cr, 0.6% C steel, commonly used for springs. During the manufacturing process prior to peening, the steel was quenched and tempered to achieve hardness in the range of 380-420 BHN. Per the manufacturer's customary practice, peening of the tension surfaces of spring leaves was performed as the final step in the manufacturing sequence. As a quality control measure, the manufacturer's practice was to perform fatigue life testing of individual leaves sampled from production runs. The basic motivation for this study was to determine factors that influenced fatigue life results with an eye to potential process improvements that could enhance spring performance. This was entirely at the manufacturer's initiative because there were no reported indications of field failure problems in any of the product lines.

Characterization of Existing Peening Process

Shot peening of the tension surfaces of individual spring leaves was performed via wheel peening equipment at an Almen intensity of 6-7C using medium hardness S390 cast steel shot to a minimum of full (100%) coverage as attained by one pass through the peening equipment. Per the author's observation, Almen saturation was achieved within the first pass. No increase in Almen arc height was observed after multiple passes. Full coverage on spring leaves was also achieved during one pass as determined by on-site direct observation/inspection using a 10X magnifier and later verified by microscopic observations at greater magnification. The peening wheel speed and conveyer belt speed were not variable and, therefore, were fixed for the process.

The manufacturer had neither a screen separator for media size control nor a device such as a spiral slide for media shape control. Media maintenance practice simply involved adding new media at intervals to make up for fallout losses during processing. The lack of media maintenance was apparent from the appearance of the in-use media as evidenced by the visually observable variability in particle size and shape. The size distributions of the in-use and new media on hand at the manufacturer's site were determined by standard sieve Ro-Tap testing and microscopic analysis per requirements of AMS-S-13165.

Author's note: The spring manufacturer was not subject to any specification requirements for peening. This information is presented here for reference purposes only.

Ro-Tap screening results from in-use and new media are tabulated below. Discrepancies between results and AMS-S-13165 requirements are highlighted in red. As can be seen, the new media size distribution conformed reasonably well to requirements with a slightly excessive amount of coarse particles retained on the 14 mesh screen. Otherwise the size distribution was within requirements. On the other hand, the in-use media displayed a marked bias of fine media particles. Photographs (10X original magnification) of representative media samples are shown in the insets of Figure 1 (page 10).

Not only was the in-use media overpopulated by fine particles, a large proportion of these were apparently the result of particle fracture. As indicated, the new media had an acceptable number of discrepant particles while the in-use media had an excessive number of discrepant particles. Easily inferred from this evidence was that lack of a screen separator and/or shape control device allowed discrepant and deteriorated media to be retained for use in the process.

In-Use Media Size Distribution

Sieve #	% Retained	Cum % Retained	AMS-S-13165 Requirement
12	0		0
14	3.5	3.5	2% Max*
16	9.5	13.0	50% Cum Max
18	21.8	34.8	90% Cum Min
20	6.7	41.5	98% Cum Min
Pan	59.5		2% Max

New Media (S390) Size Distribution

Sieve #	% Retained	Cum % Retained	AMS-S-13165 Requirement
12	0		0
14	2.8	2.8	2% Max*
16	44.0	46.8	50% Cum Max
18	51.9	98.7	90% Cum Min
20	0.1	98.8	98% Cum Min
Pan	0.30		2% Max

* Red indicates requirement violation

The surface texture of the sample peened with in-use media was much more irregular than the texture of the sample peened with new media. The new media peened surface had many more regular shaped and smooth impact impressions than did the in-use peened surface. The differences in surface texture were easily interpretable as to cause from the differences in particle size distributions and numbers of discrepant particles highlighted in the insets. Not only was the surface appearance different, the sample peened with in-use media had many secondary cracks (red arrows in Figure 1) adjacent to the main fracture after fatigue testing. The sample peened with new media had no cracks other than the main fatigue crack. There was also a fatigue life difference of about 50% in favor of the sample peened with new media. Numerous secondary fatigue cracks are often indicative of either relatively high cyclic stress or surface damage/impairment. Logically, in the present case it was a matter of surface impairment from the in-use media because the new media producted no secondary cracks after testing. Both samples were tested under the same loading conditions.

Continued on page 10


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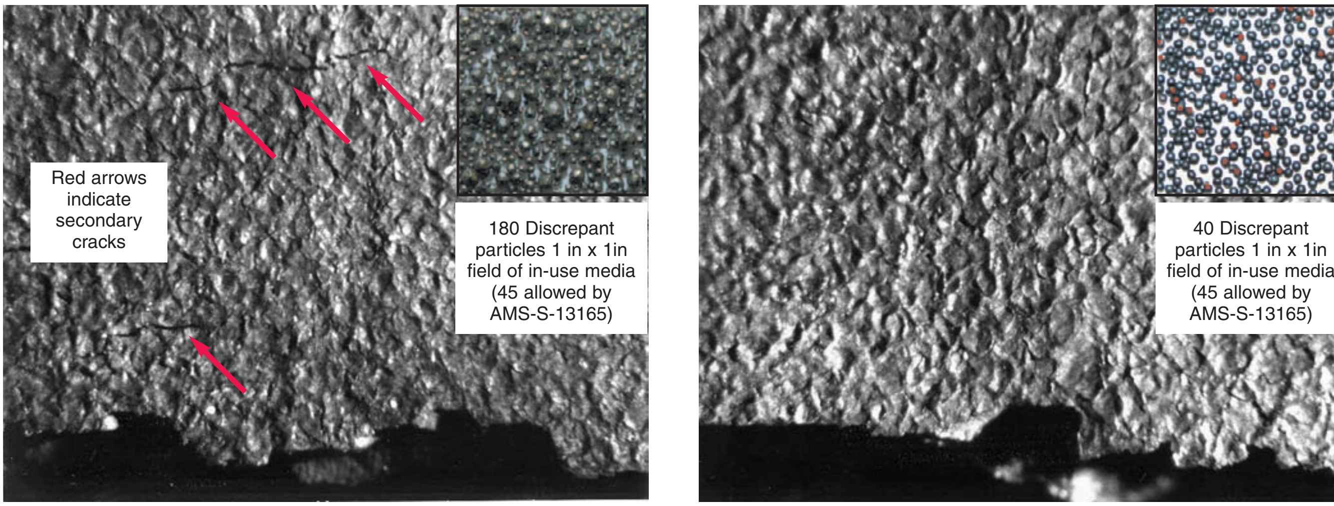

Figure 1: Surfaces Peened with In-Use Media (left) and New Media (right). Insets show media samples. Red dots indicate discrepantly-shaped particles.

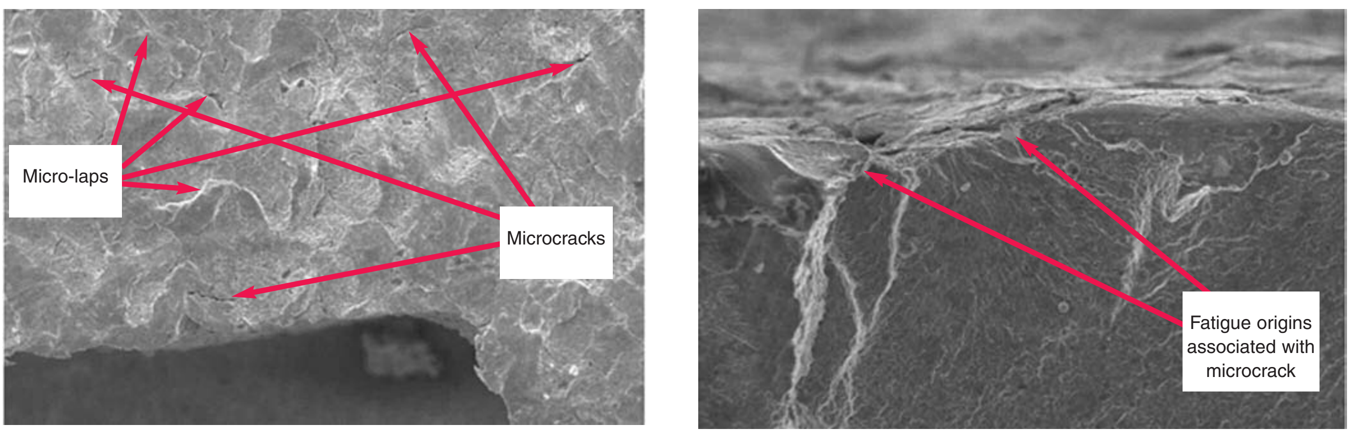

Figure 2: Micro-laps and Microcracks on Peened Surface (left SEM photo) and Fatigue Origins Associated with Microcrack (right SEM photo)

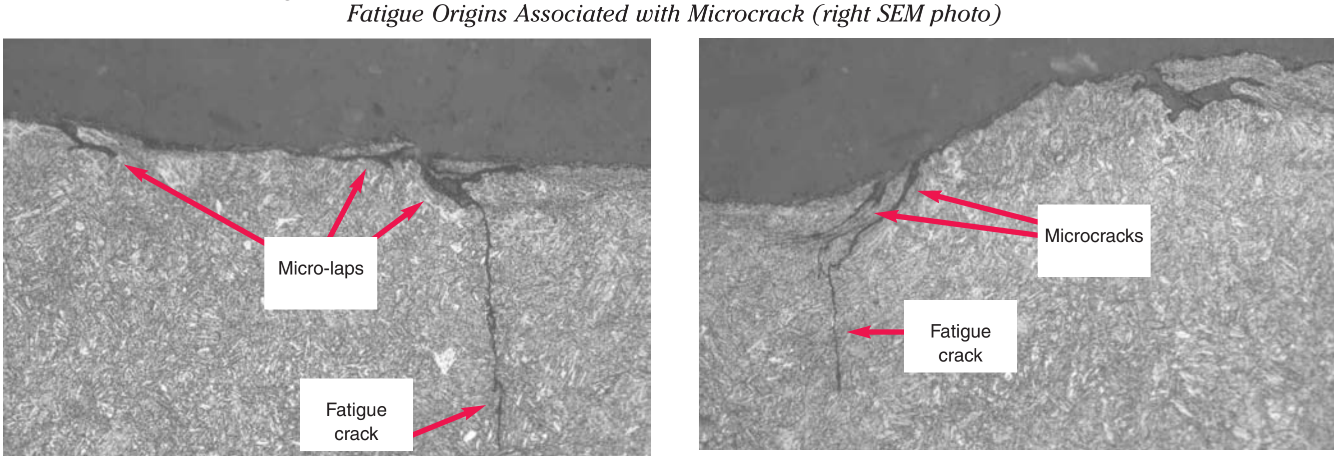

Figure 3: Metallographic Sections Showing Fatigue Cracks Emanating from Micro-Lap (left photo) and Microcrack (right photo) on Peened Surface

Scanning electron microscopic observation and metallographic sectioning through fatigue origin areas revealed further evidence of impairment of the surface peened with in-use media. As shown in Figures 2 and 3, fatigue initiation sites were associated with micro-laps and microcracks on the peened surface. Fatigue cracks that initiated on the surface of samples peened with new media exhibited no evidence of association with similar defects. Further discussion of fatigue behavior will occur in the next section.

Additional evidence for the influence of poorly-maintained in-use media as a depressant of fatigue life lay in the residual stresses induced in surface layers. Figure 4 shows the residual stress-depth distributions, obtained by x-ray diffraction analysis, from samples peened with in-use and with new media. As easily seen, the surface and near surface compressive stresses for the in-use media peened sample were much less in magnitude than the new media peened sample to a depth of about 0.015 inches

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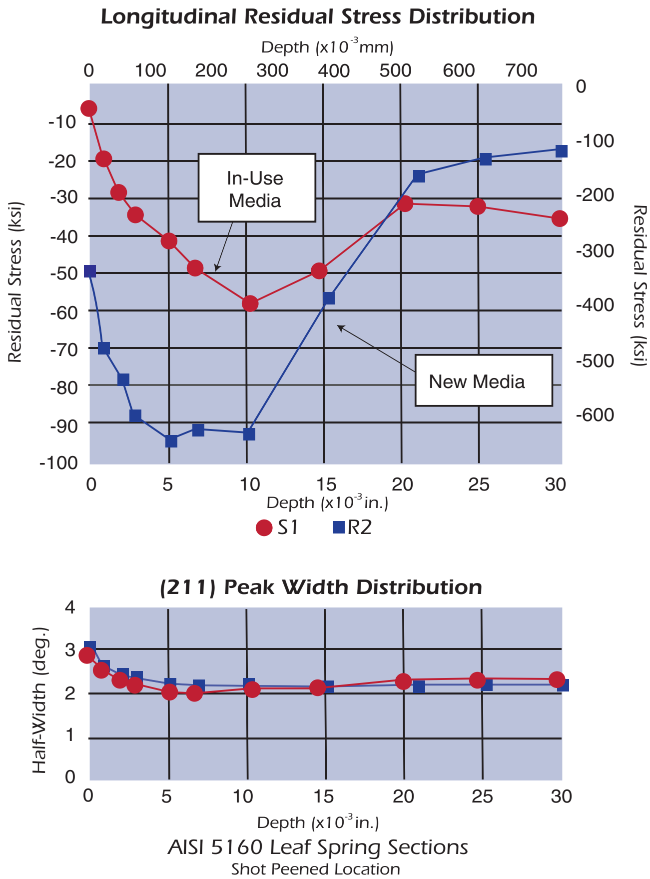

Figure 4: Residual Stress - Depth and X-ray Peak Breadth-Depth Distributions

beneath the surface. Because of the similarity in peak breadth-depth distributions, it was inferred that the larger size particles in the in-use media were dominant in producing deep residual stresses whereas the finer and misshapen particles were dominant in inducing surface damage that was responsible for reducing fatigue life.

Fatigue Life Analysis

The author analyzed all fatigue life results generated by the spring manufacturer in 2006 and in 2007 to date. As indicated previously, the author had examined some of the 2006 samples, finding greater evidence of surface micro-laps and other peening surface damage in samples peened with poorly-maintained vs. new media. It was inferred that the greater incidence of surface damage in the sample peened with in-use media was responsible for the observed lower fatigue life. In addition, the author suspected that excessive peening intensity and coverage may also have contributed to low fatigue life. Accordingly, peening of some samples at lower intensity (12A) and controlled coverage was performed at an external source. Life results from these samples were indeed greater than from the 2006 samples, but the magnitude of improvement was disappointingly small. Further disappointment was that samples peened and tested in 2007 exhibited somewhat greater fatigue lives than those peened under well-controlled conditions.

Observations from the available fatigue life results served to explain the otherwise somewhat difficult to rationalize and disappointing fatigue results. There were differences in hardness among samples and these differences contributed to life differences as revealed by the trend shown in Figure 5. Greater life was observed with increasing hardness. This trend only partly explains life differences among samples; however, the effect represented a confounding influence on interpretation of results based upon differences in surface condition.

One could probably perform a hardness-based normalization of results to improve life comparison; however, this was deemed futile because there was an even greater confounding influence present. This was not so easily resolvable. The samples in the current investigation had been tested at fairly high stress levels and, thus, life differences were masked within the "mud" of normal fatigue scatter, at least a factor of two or more in fatigue life. Historic fatigue S-N curves from leaf springs shown in Figure 6 (see reference in figure caption) serve to illustrate this effect. The author placed the dashed red circle on this figure to represent the regime of test results from the current investigation. As may be seen, the regime of current results lays in an area of convergence of S-N behavior. The very important inference from this is that normally expected fatigue life scatter (factor of 2-5) could not be expected to permit discrimination among surface treatments unless statistically large numbers of samples were tested. Certainly, the one or two samples per condition tested currently did not represent statistically large numbers. Another testing alternative would be to test at lower stress levels where the greater divergence of fatigue lives would likely permit discrimination among surface treatments. Neither testing of large numbers of samples nor testing at much lower stress levels was economically viable within the scope of this investigation. The fixed cyclic test frequency capability of the test apparatus was 0.5 Hz. Thus, the typical time duration of tests, including setup, was of the order of a day. Neither running large numbers of such tests of this duration nor running tests at lower stress levels to attain ten times greater lives was deemed economically viable. Hence, the idea of attempting to optimize peening parameters via fatigue life results from testing was abandoned. A specimen testing rather than component testing approach might have been undertaken, but this too was deemed economically unviable within constraints of the investigation.

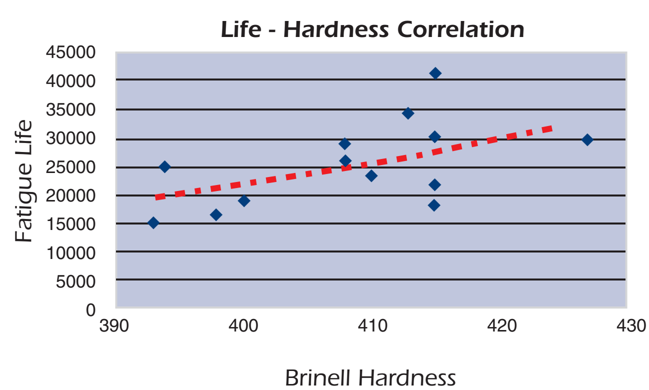

Figure 5: Leaf Spring Fatigue Life-Hardness Correlation 2006-2007 test results

Peening Parameter Investigation

Further investigation was done as to the effects of peening intensity, coverage and media size on compressive residual stress magnitude and surface roughness of the leaf spring material. The table on page 8 shows combinations and values of the parameters selected.

Surface roughness data are summarized in Figure 7, a plot of surface roughness vs. coverage for the various intensities and media sizes employed. The data show generally slight downward

Continued on page 14

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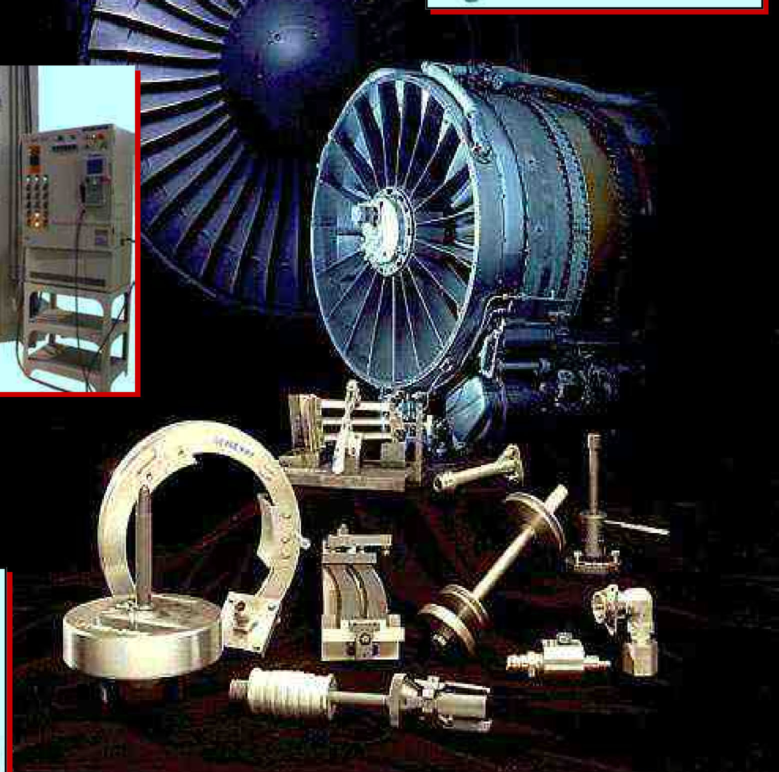

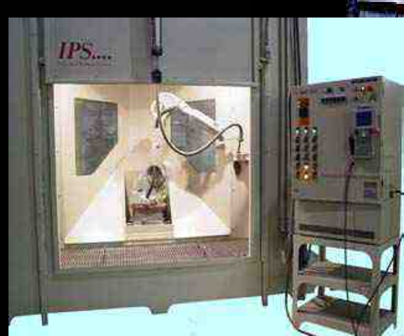

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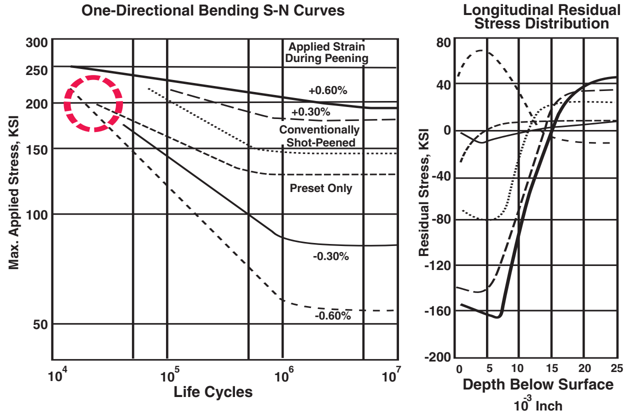

Figure 6: Historial Leaf Spring Fatigue Data.
Ref. ***Stresses and Fatigue in Metals****, Rassweiler and Grube eds.,*
Elsevier Publishers, New York, NY

	1	2	3	4	5
Media	S460	S460	S330	S330	S550
Pressure (psi)	15	50	18	60	27
Flow Rate (lb/min)	25	20	30	30	27
Nozzle	3/8" short V	5/16" long V	3/8" short V	3/8" long V	3/8" long V
Intensity	10.4A	6.5C	9.6A	5.6C	5.9C
%Coverage*	80,100,200	80,100,200	80,100,200	80,100,200	80,100,200

*One sample at each indicated coverage with other parameters fixed

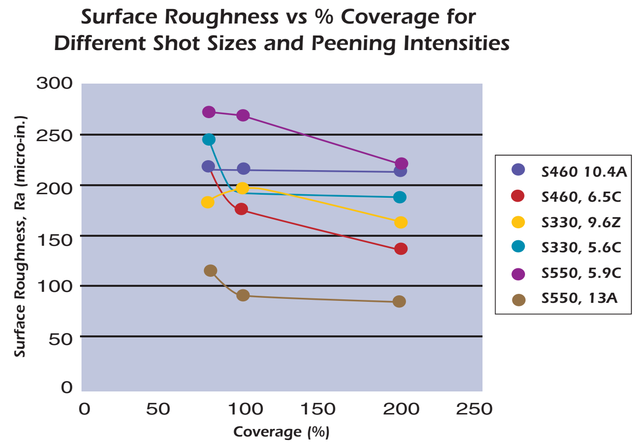

Figure 7: Surface Roughness Results from Peening Trials

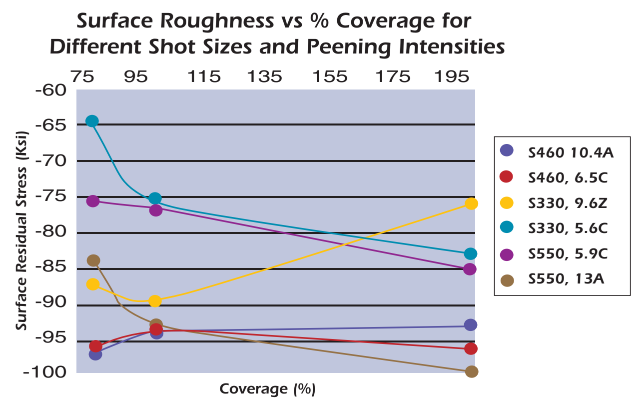

Figure 8: Surface Residual Stresses
Resulting from Peening Trials

trends with increasing coverage for given intensity and media size (i.e. surface roughness) declined with coverage increasing from 80 to 100 to 200%. Apparently the increasing number of repeated impacts at many sites served to "flatten" surface details, though the effect on roughness was deemed modest. The effect on roughness of media size at a given intensity was opposite to expectations. For a given intensity, logically one would expect a greater roughness based upon the physical requirement that a smaller particle must produce a deeper impression to have the same effect as a larger particle to produce the same intensity. Comparison of the positions of the yellow and dark blue curves representing nearly the same intensity (9.6 & 10.4A) indicates that the smaller media (S330) produced smoother surfaces than did the larger media (S460). Likewise, comparison of the bright blue and violet curves representing nearly the same intensity (5.6 & 5.9C) indicates again that smaller media (S330) produced much less roughness than larger media (S550). Curiously, an intermediate size media (S460) at a comparable intensity (6.5C) produced lower roughness than either larger or smaller media, a mixed bag for certain. The effect of intensity irrespective of media size was also a mixed bag. Here, perhaps not surprisingly, the greatest roughness was experienced for one of the greater intensities (5.9C, violet curve); however quite surprisingly, the least roughness was experienced for an intermediate intensity (13A, brown curve). The author assures the reader that the peening trials represented here were very carefully performed under computer monitored and controlled conditions, supported by appropriate Almen saturation and coverage determinations and with pedigreed media.

In most instances, surface residual stress magnitude from peening is more important than surface roughness or, if roughness must be reduced, a slight amount of post-peening metal removal will serve needs. Indeed, such material removal is likely also to remove peening-induced microlaps and enhance fatigue performance. Thus, if it comes to a choice between residual stress and roughness considerations, one should opt for the peening treatment that creates the greatest residual stress magnitude and then rely on appropriate post-peening surface treatment to achieve the desired surface finish, if necessary. Surface residual stresses resulting from the peening trials are summarized in Figure 8.

While not clear cut in all instances, greater surface residual stress magnitude was favored by peening at lower intensity. Interesting was that the best residual stress magnitude resulted from peening with the parameters, 13A intensity and S550 media, that also produced the lowest surface roughness. The effects of media size were generally mixed while the effect of coverage in nearly all cases showed a modest trend of improvement in residual stress magnitude with increasing coverage.

Summary and Recommendations

This investigation revealed that fatigue test lives from spring leaves peened via the original process were dominated by fatigue crack initiation from peening defects, namely microlaps and microcracks, induced by peening. These defects were principally the result of peening with poorly-maintained media having substantial content of broken and subsize particles. The manufacturer's fatigue life results appeared to be influenced by material hardness whereby greater hardness within the normally produced range tended to give greater fatigue life. Moreover, historic data on leaf spring fatigue also indicated that the fatigue test regime was at a level which precluded good discrimination of process effects on fatigue life. Economics prevented rectification of the latter problem and further fatigue testing has not

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been done. Additional peening trials were performed to investigate the effects of media size, peening intensity and coverage on surface roughness and surface residual stresses. Results showed that roughness and residual stress magnitude were generally favored by intermediate intensity in the range investigated, and by greater coverage over the range investigated although the latter effect was modest. The effect of media size over the range investigated was a mixed bag.

Recommendations for process improvement to the leaf spring manufacturer from results of this investigation were as follows:

- Acquire online screen separator capability for media maintenance or switch to conditioned cut wire media to greatly reduce media particle breakage.
- Reduce peening intensity somewhat from 6-7C to 12-14A. This should also serve to reduce media breakage.
- Change media flow rate and/or conveyor speed to ensure coverage within the 100-200% range.

The leaf spring manufacturer has implemented several changes including the use of conditioned cut wire media, moved the average spring hardness to the upper end of the scale and added speed controllers to the conveyor and wheel. Further fatigue testing over time hopefully will demonstrate life benefits

John Cammett Dr. John Cammett, Materials Engineer/ Metals Branch Chief, recently retired after more than 15 years service with the U.S. Navy (Navair) in the In Service Support Center to the Fleet Readiness Center East, Cherry Point, North Carolina. His more than forty-year professional career has also included materials engineering and management positions at the General Electric Company, Evendale, Ohio; Metcut Research Associates Inc. and Lambda Research Inc, Cincinnati, Ohio. His areas of expertise at Cherry Point included analysis of aircraft component failures, aircraft mishap investigations, development of repair/rework process methods and technical support of depot manufacturing/ rework/repair operations, surface integrity investigations and metallurgical applications. A Registered Professional Engineer, Dr. Cammett is a fellow of ASTM, past Chairman of Committee E-9 on Fatigue, Life Member of ASM International and past chairman of the Cincinnati Chapter, also a member of the International Scientific Committee for Shot Peening and a conferee of the 2006 Shot Peener of the Year Award. In “retirement”, Dr. Cammett is currently involved in training and consulting activities with Electronics Inc., Nadcap auditing plus other research and consulting activities in the private sector. He will be an instructor at all four of the 2008 EI workshops. Dr. Cammett may be contacted via cell phone at 1-910-382-5771 or email at pcammett@ec.rr.com.

2007 Shot Peener of the Year: Ken I’Anson

Ken I’Anson received the 2007 Shot Peener of the Year award at the U.S. Shot Peening and Blast Cleaning workshop in Arizona.

The Shot Peener magazine was pleased to award Ken I’Anson the 2007 Shot Peener of the Year award at the 2007 U.S. Shot Peening and Blast Cleaning workshop. The award is given to persons that make significant contributions to the advancement of shot peening in either commercial or academic venues.

Ken has been involved in the shot peening industry from the equipment side for 27 years. His experience is unique in that it has covered both centrifugal wheel peening and compressed air nozzle peening. He is a Sales Engineer for Progressive Technologies and focuses on airframe and land-based turbine shot peening applications. He not only understands the mechanics of the machines but the process of peening and the requirements for successful peening results.

Ken has contributed many articles and papers for the EI Shot Peening Workshop manuals and has attended the Workshops since the beginning in 1990. He has obtained Level 3 Exam certification at the EI workshops. He is also a frequent contributor to The Shot Peener magazine and the forums at www.shotpeener.com.

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Generic Almen Fixtures for Intensity Measurement in Shot Peening

David Pacciolla

Applying the shot peening process on aerospace parts can be a tough challenge as geometries can get complicated and requirements quite strict. Documented cases of aerospace component failures also remind us of the value of all processes involved in the production of a part, as every operation is important in order to achieve expected mechanical properties. In order to be as precise and flexible as possible, the use of CNC or robotic machines is often the logical way to deal with a wide variety of parts, complicated geometries and short turn-around times. As specifications are also evolving with more precise requirements in terms of intensity and coverage control, the new generations of CNC and robotic shot peening machines are often the only option that will allow meeting those requirements. However, when working with CNC machines, it doesn't take long to recognize that many current specifications were first issued when the only available methods for shot peening were manual, centrifugal wheels and simple automated nozzle machines. Requirements like the eight hours interval between intensity verifications and media analysis remind us that the new generations of precise and highly controlled machines were not available a few years ago. As specifications are evolving, it can be interesting to make them more applicable to CNC or robotic gun manipulator machines while enhancing control and quality.

The following document was produced to explain the concept of generic Almen fixtures in a CNC/robotic shot peening application, which is a technique that could be added in the near future to shot peening specifications. It will demonstrate how it can improve the accuracy of the intensity measurement during process setting and in production and the overall advantages of using this technique. It is important to note that this concept hasn't been fully validated yet. A test protocol is currently being developed in order to verify the basis of the generic Almen fixture concept and evaluate its validity for shot peening. The denominations given to various types of Almen fixtures are used for this document only and are currently not related to any documented shot peening specification.

The Concept

An Almen fixture is an assembly of Almen holders used to measure the intensity of the shot stream for given machine parameters. Although most specifications don't mention several types of Almen fixtures, it is possible to separate the widely used Almen fixtures in two types, the simulative and semi-simulative. The simulative Almen fixture is based on the geometry of the part being shot peened, simulating the position and angle of each surface relative to the other, which is the requirement of most shot peening specifications for the Almen fixture configuration. The simulative fixture should also be installed in the same work holding fixture as the actual production part, and be peened under the same conditions. This type of fixture is habitually constructed from a rejected part modified to fasten Almen holders, or from a welded assembly that orients the holders to replicate the surfaces to be verified.

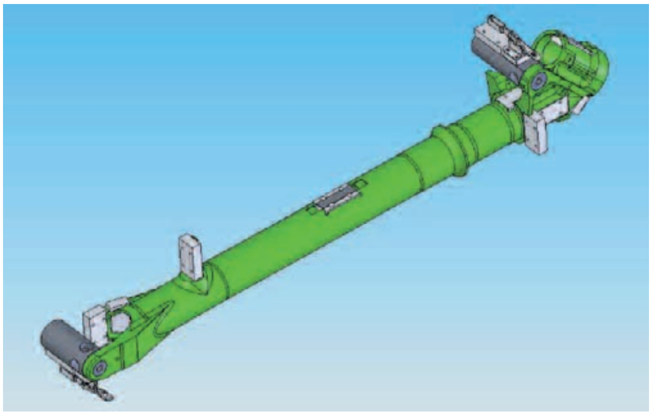

Figure 1: Simulative Almen fixture

Semi-simulative Almen fixtures are mainly aimed at measuring the intensity in bores or in holes when using rotary lances or deflectors. Those fixtures are already commonly used in shot peening applications on many types of shot peening machines, from the fixed position lances (non mounted on a manipulator arm) to the CNC/robotic manipulated lances. In both cases, it is an accepted procedure to control only the shot peening parameters of the lance, and not the position of the fixture in the envelope of the machine. In other words, the fixture can be placed anywhere in the machine, as long as the lance is positioned and translated along the axis of the bore. The semi-simulative Almen fixture thus replicates the geometric parameters (angle of incidence, distance) of the shot stream in the bore, but not its position in the workspace of the machine. It also replicates the conditions of rebound and turbulence that can interfere with the shot stream.

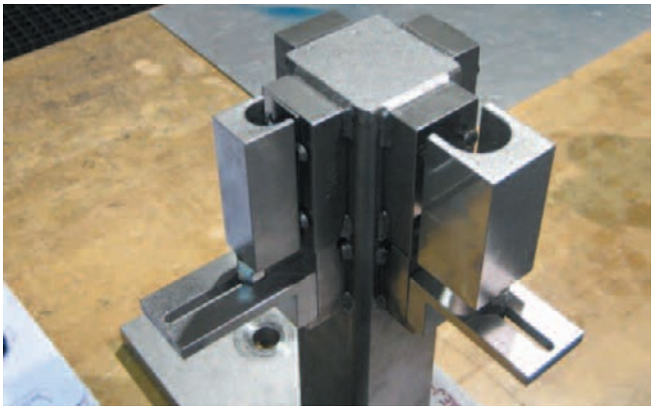

Figure 2 - Semi-simulative Almen fixture for small bores (1.500" and 0.750" diameters in that setup)

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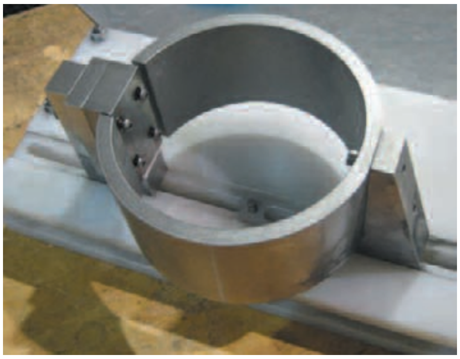
Figure 3 - Semi-simulative Almen fixture for large bores (5.000" diameter in this setup)

The use of semi-simulative Almen fixtures has given the concept of generic Almen fixtures for nozzle peening applications. This new concept was established based on the fact that a semi-simulative Almen fixture doesn't have to exactly replicate the part (the position of the bore on the part) because the machine can ensure the position of the lance in the bore. Considering that point, we can extrapolate that this procedure could be applied to external peening. On CNC/robotic shot peening machines, the accuracy of the manipulators ensures that the position of the nozzle relative to the shot peened surface is precisely controlled in terms of distance and impingement angle. Those two parameters being handled by robot programming, Almen fixtures can be used to control the other intensity influent parameters as air pressure, media flow and media properties. It is important to note that those parameters are independent from any of motion-related parameter. The next section defines the concept of generic Almen fixtures, the way they are used and their limitations.

The use of generic Almen fixture is based on the fact that the new generations of shot peening machines, through the use of CNC or robotic motion, have precise control of the position of the nozzle in the work envelope of the machine. As those machines are habitually programmed using teach mode, it important to note that if generic Almen fixtures are to be used, teach mode should be limited to simple nozzle motions, so that direct measurements of impingement angle and distance can be performed directly on the part used for programming. If the geometry calls for complex trajectories in which constant impingement angle and distance can't be assured by teaching, offline programming should be used. Offline programming consists of computer generation of nozzle trajectories using 3D model of the part, along with simulation and collision check software. Those tools allow a really precise control of the motion of the nozzle in the work envelope, along with the possibility of specifying precise impingement angle, distance and feed of the shot stream relative to the part.

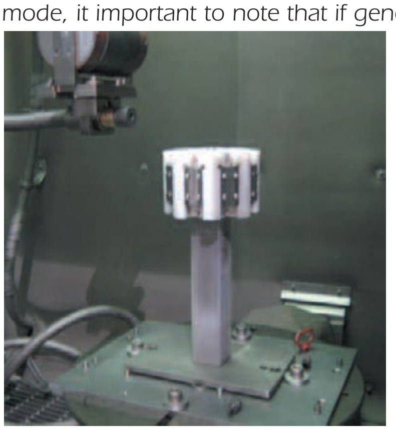
Figure 4 - Generic Almen fixture

When using a generic Almen fixture, the nozzle is first positioned as in figure 4 and shot peening parameters (air pressure and media flow rate) are stabilized after starting the blast nozzle. The blast gun is then moved down with a given distance, impingement angle and feed relative to the strip. Once the Almen curve has been built and the saturation point is within the requirements, the impingement angle and distance will be associated to a recipe in the machine, along with air pressure and media flow rate. This recipe will then be used in offline or teach programming for given surfaces on which impingement angle and distance are physically possible. If many combinations of impingement angle and distance are necessary to shot peen all surfaces of a part (because of shading or machine limits), every one of them will be assigned to a recipe, and every recipe will be tested on a separate strip of the fixture when performing intensity verification at the required time intervals.

To get a good understanding of the concept, it is important to separate intensity from coverage in the shot peening process. As definition, intensity is the measurement related to the kinetic energy of the shot stream when it hits the surface of the part and coverage is the percentage of the surface which is covered by shot peening dimples. Given those definitions, we can dissociate the test strip saturation time and the 100% coverage exposure time of the part. This can be simply explained by the fact that the high hardness spring steel used for Almen strips will take a different exposure time to reach 100% coverage than a part made of aluminum or any other material. Based on those facts, we can control intensity on the generic Almen fixture, and then use a rejected part to perform coverage mapping for each surface with the appropriate recipe, which ensure uniform and optimal coverage over the whole part. More information on the distinction between intensity and coverage determination can be found in SAE documents AMS 2430 (shot peening, automatic), SAE J2277 (shot peening coverage) and SAE J443 (procedure for using standard shot peening test strips). It is important to note that the concept of generic Almen fixtures is based on the distinction between intensity and coverage, and the understanding that the exposure time at saturation generated by the Almen curve does not influence the exposure time (or nozzle surface feed in CNC/robotic machines) needed to obtain 100% coverage.

The use of generic Almen fixtures requires CNC or robotic equipment equipped with precise monitoring and control devices. This monitoring ensures that all parameters that are important for intensity and coverage are controlled, stabilized and that production is stopped if a problem occurs. Generic Almen fixtures as presented are aimed at pneumatic shot peen machines that allow control of the shot stream compared to a wheel blast machine which has a wide blast pattern with variable impingement angles. However some examples of intensity verification on wheel machines have been known to work a lot like the present concept, measuring the properties of the shot stream in a position different than the position of the part. It is, however, out of the scope of this document to describe those techniques.

Given those assumptions, there is no necessity to perform intensity measurement on a fixture that simulates the actual geometry of the part when using equipment that controls the "geometric" parameters (angle of impingement, nozzle distance) with good accuracy. However in some situations the simulative and semi-simulative Almen fixtures are still necessary, like in the following cases:

- Shot peening is performed with rotary lances.
- Geometries can cause important shot rebound that could alter intensity.
- Geometries can cause turbulences which could affect the shot stream.

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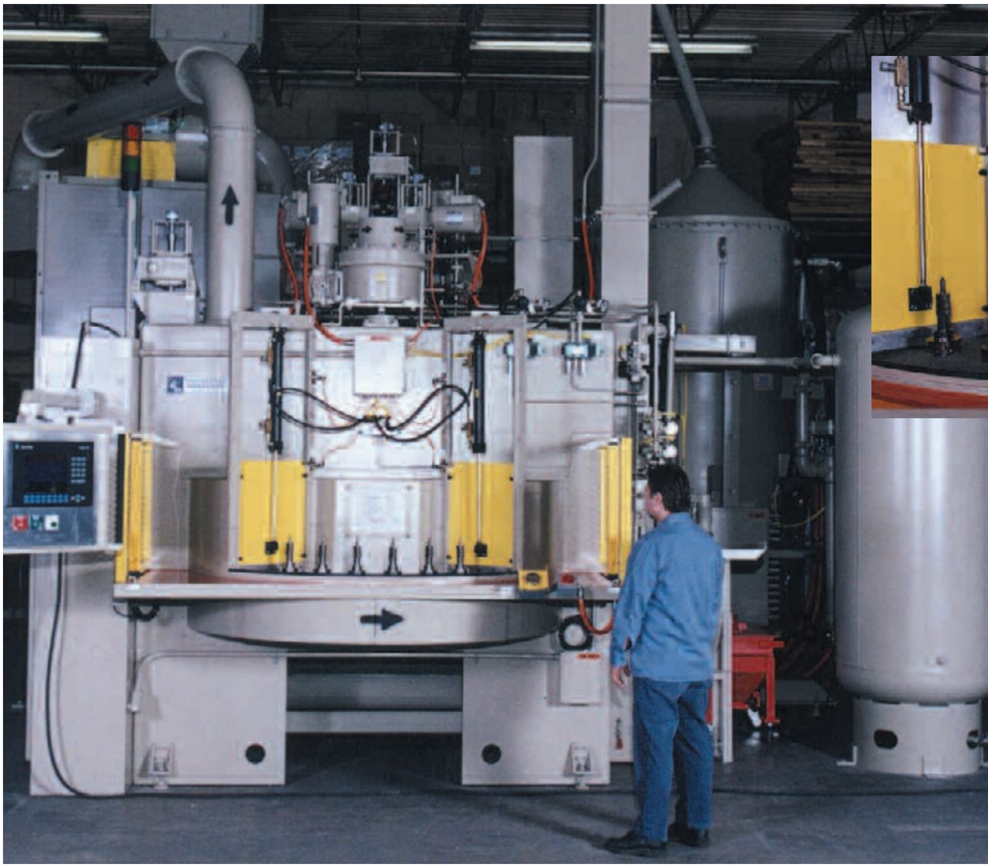

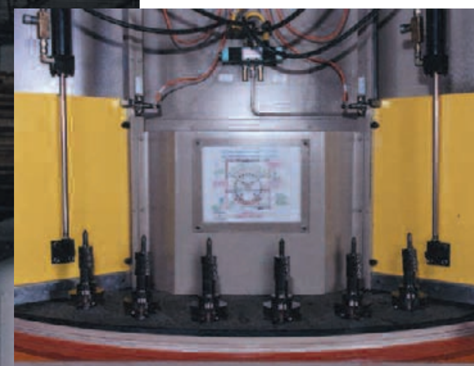

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- Media build-up could cause interference with the shot stream.

Improvement of Accuracy

From the results of preliminary testing, the use of generic Almen fixture can improve accuracy when building Almen curves, as well as during intensity verification in production. It is important to note that the following observations are qualitative and based on experience in building saturation curves, as no qualification or any other quantitative data is available at the moment.

- An important point when using Almen strips, as stated in SAE J443, is that the test strip shall exhibit uniform coverage. In cases where simulative test fixtures are used, it is often impossible to ensure that the coverage is uniform. When inspecting a strip after an exposure time greater that the saturation time, the strip will probably show complete coverage, but in most cases it will be impossible to prove that the whole surface is at exactly the same coverage. This can be explained by the fact that all shot peening machines (wheel or air blast, CNC or not) rely on multiple passes on the part to attain complete coverage. When using generic Almen fixture, a single pass is performed on the strip with a given feed rate. This ensures uniform coverage on the strip and thus greater precision or arc height measurement.
- Nozzle motion programming often calls for complex curved trajectories, on which it is hard to specify a given and uniform feed on the part surface (except when using offline programming). As feed is really important when building a saturation curve, the concept of performing a single pass, with a simple motion at a given feed will allow a greater level of correlation between the feed (which is correlated to exposure time) and the arc height. This more precise correlation again allows more precision when building saturation curves.
- When building a simulative Almen fixture from a scrap part or a welded frame, Almen holders often have to be welded in place. This causes a risk of warping the grinded surface, as well as altering the hardness locally near welding points. Generic Almen fixtures don't have those problems making them more compliant to SAE J442. Welded Almen fixtures can also become distorted from being shot peened numerous times, which can cause errors in intensity evaluation.
- Building a simulative Almen fixture from a rejected part or a welded frame is a complicated task, which involves designing the fixture from a 3D model, producing detail drawings for machining, performing machining, welding or attaching the Almen holders and often heat treat the fixture. This takes a considerable amount of time in process preparation in a context where lead time is an extremely important variable. The use of generic Almen fixtures eliminates all the mentioned tasks, which can easily cut many days and even weeks of process preparation for complex parts.

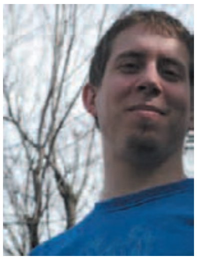
Conclusion

With the introduction of new materials, more complex shapes and stringent requirements in aerospace components, it is obvious that intensity measurements techniques have to be adapted to the new generations of CNC/Robotic shot peening equipment. Those new machines have greater control on the process oriented variables and are moving from non-precise and poorly controlled machines to precision oriented equipment when the proper programming techniques are used. The implementation of offline programming allows greater consistency on the application of the shot stream, which should allow us to step away from simulative Almen fixtures as long as the limitations mentioned before are considered. The next step is to verify if the machine can keep all intensity influent parameters constant in the work envelope. This step is being developed in a validation plan which will be aimed at verifying the influence of the motion and position of the blast gun (which changes the blast hose radiuses, position and vertical length) on media flow and air pressure. To follow the aerospace industry's highly developed technology, the generic Almen fixture is only one of the steps that have to be made toward the replacement of the Almen technique by shot velocity sensors or other measurement devices. This could lead to development and acceptance of closed loop intensity control systems implemented in shot peening equipment.

CNC/robotic machines have many advantages in application of shot peening, especially in aerospace applications. The only downside of the new generations of shot peening machines is that the actual specifications are not yet fully adapted to a high level or process control, by requiring testing and validation to be performed according to old technology and poorly controlled techniques. The use of generic Almen fixture is one of the ways that can lead to a more efficient use of CNC/robotic shot peening equipment while still complying to the main specifications requirements. As more testing is performed, the concept will be refined to enhance efficiency and quality of results during production and process settings. ●

References

AMS-S-1316 5Shot Peening of Metal Parts
SAE J442 Test strip, Holder and Gage for Shot Peening
SAE J2277 Shot Peening Coverage
SAE J443 Procedures for Using Standard Shot Peening Test Strip
AMS 2430M Shot Peening, Automatic
AMS-2432B Shot Peening, Computer Monitored Work Biography



David Pacciolla has a bachelor's degree in mechanical engineering with main interests aimed at mechanical design, computer aided design and manufacturing, as well as fabrication processes. He started his career implementing the shot peening department of Tekalia Aeronautik, and is today responsible of development and implementation of new processes and equipment for surface treatments of aerospace components. Comments or questions about this article would be greatly appreciated and can be sent to dpacciolla@tekalia.com.

Properties of Air-Blast Shot Streams

Dr. David Kirk

INTRODUCTION

Shot peening involves three factors – Shot Stream, Machine and Workpiece. These three factors interact to determine the prime-objective parameters of coverage and peening intensity. Fig.1 illustrates these interactions.

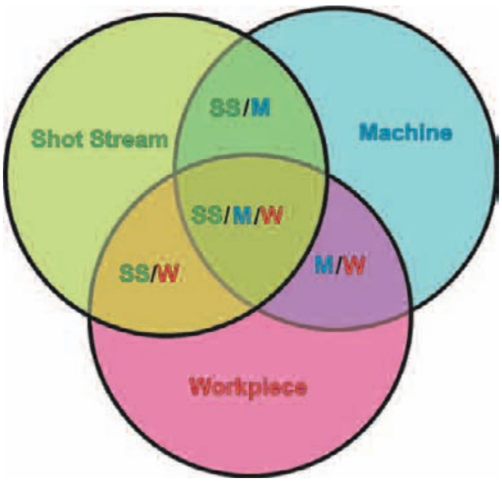


Fig.1. Interaction of Shot Peening Factors

Fig.1 represents the entirety of shot peening operations. For a particular operation the workpiece parameters (such as material, hardness, size and geometry) will be set by the customer. The prime-objective parameters of peening intensity and coverage will also be pre-determined, together with the shot type and size that are to be used. All (?) that the shot peener has to determine is the appropriate combination of shot stream and machine parameters, SS/M, that will satisfy the customer's requirements. "Parameter" in this context can be defined as "A measurable, variable, quantity that determines the outcome of an operation".

Shot streams have two components – 'inbound' and 'outbound'. The inbound shot stream component emanates from the nozzle whereas the outbound component consists of particles rebounding from a component's surface. This article is concerned with the quantification of both shot stream components. Quantification is an essential feature of modern engineering process control. A case study of inter-shot collisions is used to show how quantified properties can be employed to analyze significant peening problems.

The simplest geometrical model of an inbound air-blast shot stream is that of a truncated right circular cone. That means that the 'point' of the cone is missing, the axis is at right angles to the base and the base of the cone is a circle. The properties of an inbound shot stream are determined by the magnitudes and interactions of five primary parameters:

1. Mass Flow
2. Nozzle Diameter
3. Cone Angle
4. Shot and
5. Shot Velocity.

PRIMARY PARAMETERS

Fig.2 illustrates the general concept of a truncated right circular cone together with the five primary parameters.

Mass flow is the rate at which shot is being fed from the nozzle into the shot stream. Machine setting allows this to be quantified to some degree of accuracy. A MagnaValve setting of, for example, 6kg per minute, is equivalent to $100 g \cdot s^{-1}$.

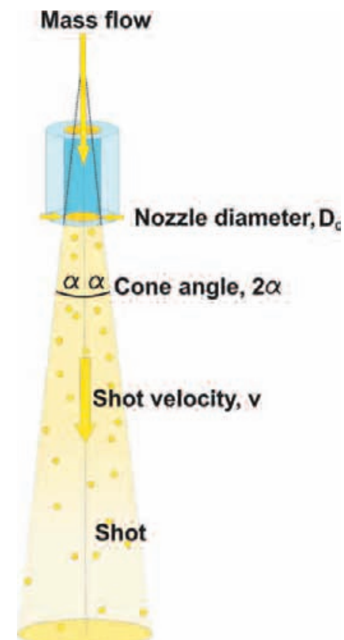


Fig.2. Primary parameters of inbound shot stream - shown as a truncated right circular cone.

Nozzle diameter, D_0, is a matter of a few millimeters, but is not constant due to progressive enlargement caused by wear.

Cone angle, 2α, is a vital parameter that defines the 'spread' of the shot stream. Its magnitude depends upon the type and length/diameter ratio of the nozzle. A long narrow cylindrical-bore nozzle will have a small cone angle-compared with that for a short wide nozzle. Convergent/divergent-bore nozzles will have cone angles regulated by the divergence angle. Commercial nozzles have a cone angle within a range of 5 – 45°.

Shot velocity, v, is a function of the air-pressure being applied. It's magnitude can be measured using either high-speed photography or inductive instruments. Alternatively the velocity can be inferred from measured indentation diameters imposed on material of known hardness. The magnitude is affected by the mass flow value.

Shot is simply the type of shot specified for a particular operation, e.g. S230. Specification ensures the chemical composition, hardness and size range of the particles.

GEOMETRICAL PROPERTIES

The truncated right circular cone model is reasonably-accurate for most shot streams. Fig.3 (page 26) indicates the important geometrical properties of this model.

The circular cross-section at any distance, S, from the nozzle has a diameter AB with a corresponding area of $\pi AB^2/4$. This area increases with both S and divergence angle, 2α. Fig.3 shows the relevant geometry of the situation.

The nozzle diameter, D_0, and the semi-angle, α, are defining shot stream parameters.

The cone has an imaginary origin at O and the circular base has a diameter D_S which varies with distance, S, from the nozzle. Equation (1) gives the relationship between circular base diameter, nozzle diameter and semi-cone angle.

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$$D_S = D_O + 2S.\tan\alpha \quad (1)$$

We can only use equation (1) if we know the value of tanα. This has to be obtained by experiment e.g. by firing a stationary shot stream held at right angles to a stationary flat test plate and measuring the diameter, Ds, of the resulting indentation pattern. The nozzle diameter, Do, and the nozzle-to-plate distance, S, are also measured. Alternatively, we could measure the average width (Ds) of the indentation 'trail' produced as the nozzle is moved at a fixed distance from a flat test plate. It follows from equation (1) that:

$$\tan\alpha = (D_S - D_O)/2S \quad (2)$$

As an example: a given shot stream fired from a 10mm diameter nozzle produces a 50mm diameter indentation pattern when the nozzle is 200mm from a flat plate. Substituting these values into equation (2) gives that tanα = (50 – 10)/400 = 0.10. (The corresponding value for α is 5·7°.) Armed with a known value for tan· we can now estimate the shot stream diameter for any distance from the nozzle. We can also estimate the cone-section area variation with distance, As, using:

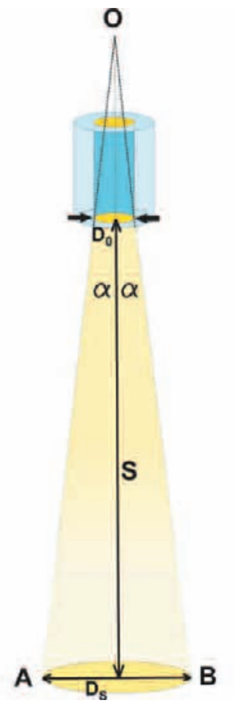

Fig.3. Geometry of an inbound conical shot stream.

$$A_S = \pi(D_O + 2S.\tan\alpha)^2/4 \quad (3)$$

The change of stream diameter with distance from the nozzle is a **linear function** whereas that for area change is a **quadratic function**. The difference is illustrated in fig.4.

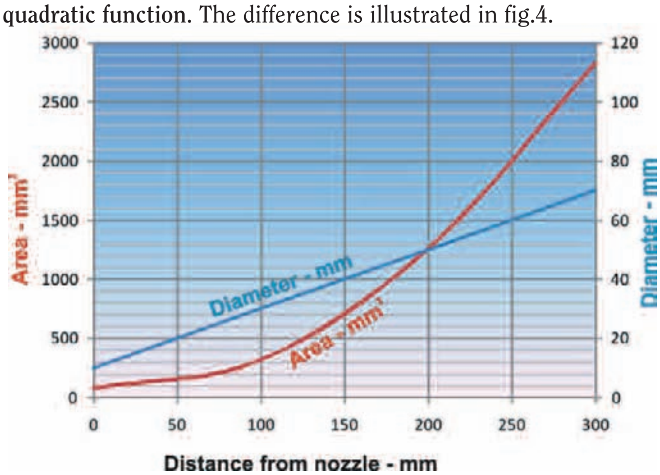

Fig.4 Variation of cone diameter and cross-sectional area with distance from a 10mm diameter, 5.7°, nozzle.

The divergence angle, 2α, can be in a range of 5° to 45° - depending on the type of nozzle being used. A smaller range, say 10° to 24° is normally employed, as illustrated in fig.5.

An elliptical shape is formed when a circular cone is intersected by a flat surface, see fig.6.

The ellipse has an area that is larger than that of the circle, diameter AB, formed at the same distance S from the nozzle. As a good approximation the major axis of the ellipse, DC, equals AB/cosθ. If, for example, θ is 45° then the area of the ellipse

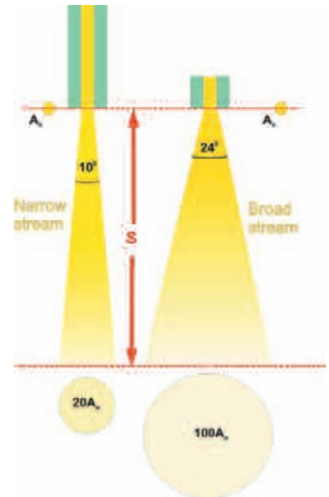

Fig.5 Narrow and broad inbound shot streams.

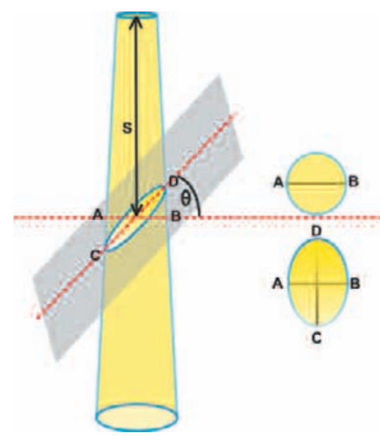

Fig.6. Ellipse formed by flat surface intersecting a circular cone at an angle θ.

(π·a·b) is 1·4 times that of the circle, diameter AB, see insets on right of fig.6.

DYNAMIC PROPERTIES OF INBOUND STREAMS

Shot streams are made up of vast numbers of high-velocity particles. Collectively these streams of particles have dynamic parameters. The particles also have static parameters that are well-documented: size distribution, shape, material, hardness and density. Machine settings determine the rate and velocity at which shot is fed into the shot stream. These, in turn, control the dynamic shot stream parameters.

Mass Flow and Mass Flux

Mass flow, **MF**, is simply the mass of shot being fed into the shot stream per unit of time. Mass flux, **MXs**, on the other hand, is the mass of shot crossing a unit of area per unit of time. Hence:

$$MX_S = MF/A_S \quad (4)$$

where As is the circular cross-sectional area at a distance, S, from the nozzle.

As an example, consider a machine setting whereby 6kg per minute of shot is constantly being fed into a 10mm diameter circular-section nozzle. Mass flow, **MF**, equals **100g·s-^{1}**. The cross-sectional area, As, at the nozzle is **78·5mm^{2}** so that the nozzle mass flux is **1·27g·mm^{-2}·s^{-1}**. Mass flow, **MF**, is constant but the mass flux varies with the cross-sectional area of the shot stream. Substituting the value for As given by equation (3):

$$MX_S = 4MF/[\pi(D_0 + 2S.\tan\alpha)^2] \quad (5)$$

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For instance, if MF = 100·g·s^{-1}, D_0 = 10mm, S = 200mm and α = 3·4° then MX_S = 0·11g·mm^{-2}·s^{-1}.

Particle Flow and Particle Flux

Particle flow, PF, is the number of shot particles being fed into the shot stream per unit of time. **Particle flux, PX_S,** is the number of particles crossing a unit of area per unit of time. If we know the value of particle flux we can predict the rate at which the shot stream is making indentations on a component.

Particle flow is given by:

$$PF = MF/m \tag{6}$$

where **m** is the average mass of an individual particle fed into the shot stream.

The simplest way of determining **m** is by weighing a known number of shot particles. That requires a high-precision set of scales - since S70, S170, S230 and S930 cast steel shot particles have average masses, **m**, of about 0·12, 0·54, 1·48 and 89.8mg respectively. If the mass flux was 100g·s^{-1} then the corresponding particle flux values would be 830,000, 190,000, 68,000 and 1,100s^{-1} respectively. As 'ballpark' figures, the range is from about one million to about one thousand particles per second depending on shot size (for the assumed mass flow of 100g·s^{-1}).

Particle flux, PX_S, is given by:

$$PX_S = PF/A_S \tag{7}$$

Consider, for example, a 36mm diameter shot stream striking a flat plate. The impact area is approximately 1000mm^2. The rate of impacting would then range from 1000 particles to 1 particle per square millimeter per second depending on steel shot size.

Particle Space Density and Particle Space Occupancy

Two significant questions are: "How many particles are there per unit volume of space in the shot stream?" and "How much space is occupied, on average, by each shot particle in the shot stream?"

Particle space density, **PSD**, is the number of shot particles per unit volume of space. PSD depends upon the mass flow, MF, particle velocity, v, cone-section area, A_S, and average mass of a particle, m. Equation (8) gives the corresponding relationship:

$$PSD = MF/(v \cdot A_S \cdot m) \tag{8}$$

As an example: if **MF** = 40g·s^{-1}, v = 60m·s^{-1}, A_S =400mm^2 and **m** = 0·54mg (S170 shot) then equation (8) gives that **PSD** = 0.0031mm^{-3} (or 3.1 per cm^3).

Fig.7 is a simulated 'time-lapse picture' of the positions of the three shot particles (as estimated in the preceding example) in a one centimeter cube. The 'time-lapse' is 1/6000th of a second which is the time required for particles to travel 1 cm when at a speed of 60m·s^{-1}. On average, three particles will have entered and three will have left the cube in that period. Particle positions are *almost* random ("almost" because particles cannot share the same space).

Particle space occupancy, **PSO**, is the volume of space occupied, on average, by each shot particle. It is simply the reciprocal of PSD so that:

$$PSO = v \cdot A_S \cdot pm/MF \tag{9}$$

For the values in the previous example, PSO = 323mm^3. That is equivalent to one particle per 7mm-sided cube.

Particles in flight, N

The number of particles in flight, **N**, is the total number of particles in the inbound shot stream between the nozzle and a specified distance, S. This can be estimated using the equation:

$$N = MF \times S/(v \times m) \tag{10}$$

For example, if **MF** = 40gs^{-1}, S = 300mm, **v** = 60m.s^{-1} and **m** = 0.54mg then **N** = 370.

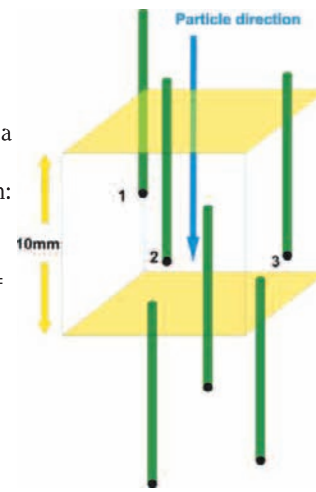

Fig.7. 'Time-lapse' representation of inbound particle positions for a PSD of 3 per cm^3.

Kinetic Energy

Every shot stream contains, at any given instant, a large number of particles moving at high velocity. Each particle has a kinetic energy, **E**, given by the most significant equation in the whole field of shot peening:

$$E = \tfrac{1}{2}mv^2 \tag{11}$$

where **m** is the mass of the particle and **v** its velocity.

The velocity of shot particles is generally in the range of 10 to 100m s^{-1}. *For an individual shot particle,* we can combine a known shot velocity with its known mass to give its kinetic energy value. Fig.8 shows a 'log-log' plot of the variation of kinetic energy with velocity for different cast steel shot sizes. The range of energies involved is so enormous that there is no realistic alternative to the use of log-log plotting.

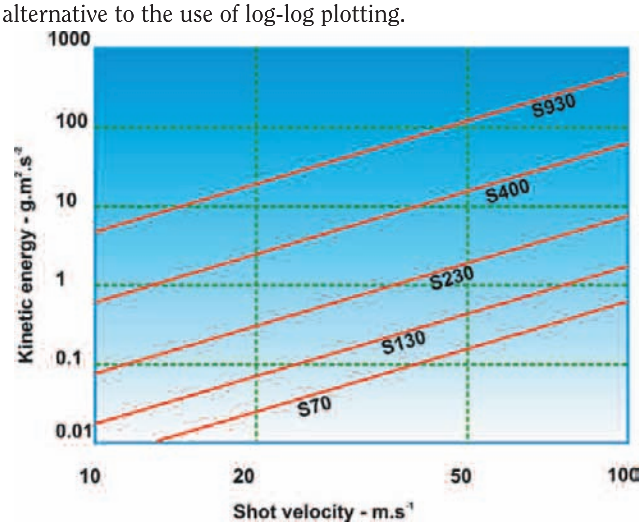

Fig.8. Variation of kinetic energy with size and velocity of cast steel shot particles.

There is a direct correlation between kinetic energy of particles and 'saturation intensity'. Coverage, on the other hand, is a combined function of kinetic energy flux and peening time.

Kinetic energy flow, KEF, is the total kinetic energy entering the shot stream per unit of time, E/t. Using equation (11) we have that:

$$KEF = \tfrac{1}{2}MF \cdot v^2 \tag{12}$$

For a mass flow, MF, of 0.1kg·s^{-1} (6kg/min) of particles travelling at 60m·s^{-1} equation (12) gives that the kinetic energy flow is 180kg.m^2.s^{-3} – equal to 180W.

Kinetic energy flux, KFX, is the total kinetic energy of the particles crossing a unit of area per unit of time. This can be estimated by combining equations (7) and (11). *Continued on page 32*

Continued from page 30

Hence:

$$KFX = \tfrac{1}{2}mv^2 \cdot PF/A_S \qquad (13)$$

OUTBOUND SHOT STREAM PROPERTIES

Shot particles rebound from the component's surface producing an 'outbound' shot stream that interacts with the inbound shot stream. The geometry of the outbound stream is largely governed by that of the component at the area of impact. It is therefore impossible to generalize about the outbound stream's properties. Fig.9 shows just one type of situation - in which a narrow shot stream rebounds from a flat-surfaced component. Very close to the component's surface the outbound shot stream has a particle space density that exceeds that of the inbound stream. For example, if we have three particles per cubic centimeter inbound at $60 m{\cdot}s^{-1}$ rebounding at $45 m{\cdot}s^{-1}$ then there must be (on average) four outbound particles in the same cubic centimeter.

CASE STUDY – INTER-SHOT COLLISIONS

A very important property of the outbound shot stream is the opportunity that it affords for particle collisions. Some of the rebounding outbound particles must collide with inbound particles. Collisions vary over a range from 'slight glancing' to 'head-on'. Head-on collisions can lead to fracture of shot particles because of the combined velocities – just as with an auto crash. The rebound velocity depends upon the inbound velocity and on the coefficient of restitution between the particle and the component surface. As a typical example, the rebound velocity is 70% of the inbound velocity. For an inbound velocity of $60 m{\cdot}s^{-1}$ a head-on collision between inbound and outbound particles would then be at about $100 m{\cdot}s^{-1}$ (220 m.p.h.). Glancing collisions divert the incoming particles so that they strike components at less favorable angles than if they had not suffered a collision. A 'serious collision' occurs at a much greater velocity than does simple particle/component impacting. It is therefore likely to be the dominant cause of shot breakage – especially for relatively-brittle shot particles.

Fig.9. Inbound shot stream generating outbound shot stream.

Important questions are: "What is the probability of a 'serious collision'?" and "What factors affect the frequency of collisions?" Reasonable estimates can be obtained using the semi-descriptive approach that follows. More precise estimates require complex analytical statistical methods.

Collision Circles

Consider just two 0·5mm diameter particles, one inbound and one outbound, that are 'set on a collision course'. The center of one particle must lie somewhere within a 1·0mm diameter 'collision circle' that coincides with the center of the other particle, as illustrated in fig.10. An inbound particle with its center at A will make a 'head-on' collision with the outbound particle. If the center is at B, on the edge of the collision circle, it will only just make glancing contact. The area of the 'collision circle' is $\pi{\cdot}d^2$ where d is the diameter of the particle.

Glancing-angle collisions will, however, have no significant effect on peening efficiency. A 'serious collision' could be defined as one where the diameter of the inbound particle lies within a circle that is half of that of the collision circle. For such impacts the inbound particle is diverted to a striking angle of 30˚ or less. Hence we can define a 'serious collision circle', as shown in fig.10 with an inbound particle having its centre at C. The area of the 'serious collision circle' is $\pi{\cdot}d^2/4$, where d is the diameter of the particle.

Collision Probability

The probability, **p**, for any type of single pair collision depends upon the particle space density and the particle diameter. *If*, for example, we have just one pair of 0·5mm diameter particles in a one centimeter cube then since **p = area of collision circle/area of cube face** we have that **p = π/100 or 3·2%**. The area of a 'serious collision' circle is only a quarter of that of the collision circle. The probability of a 'serious collision' is therefore only a quarter of that for 'any type of collision', e.g. 0·8% (for the previous case).

The probability, P_T, of an 'any type' collision occurring within a defined volume (1 cubic centimeter) for an individual inbound particle increases with the particle space density, as shown by equation (14):

$$P_T = \frac{\pi.d^2}{100} \cdot \frac{4}{3} \cdot \text{P.S.D.} \qquad (14)$$

If, for example, P.S.D. equals 3 then we have 4 outbound particles in our defined volume (assuming that the rebound velocity is 75% of the inbound velocity). For d = 1mm then P_T = 12·8%. The probability of *one particular* particle having a 'serious collision' is a quarter of that for an 'any type' collision – 3·2% for this example.

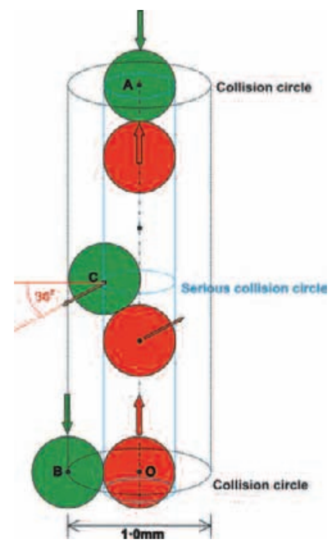

Fig.10. Collision circles for inbound and outbound particles.

Collisions will occur not only in just one centimeter cube but also in other such cubes that are in the same line. The number of such cubes depends upon the geometry of the stream/workpiece interface. Flat component surfaces, as shown in fig.9, would generate the largest number and hence the greatest multiplying factor.

The collision probability for every shot particle fired at a component is directly proportional to the particle space density of the shot stream. Particle space density is, however, directly proportional to the mass flow, MF. Hence we have the important relationship that:

The collision probability for every shot particle fired at a component is directly proportional to the mass flow of the shot stream.

Fig.11 illustrates the linear relationship between collision probabilities and mass flow. It should be noted that the actual values are specific to the shot variables used in the previous example (0·5mm diameter steel shot at $60 m.s^{-1}$ and a $400 mm^2$ shot stream cone cross-section).

DISCUSSION

All of the significant shot stream properties

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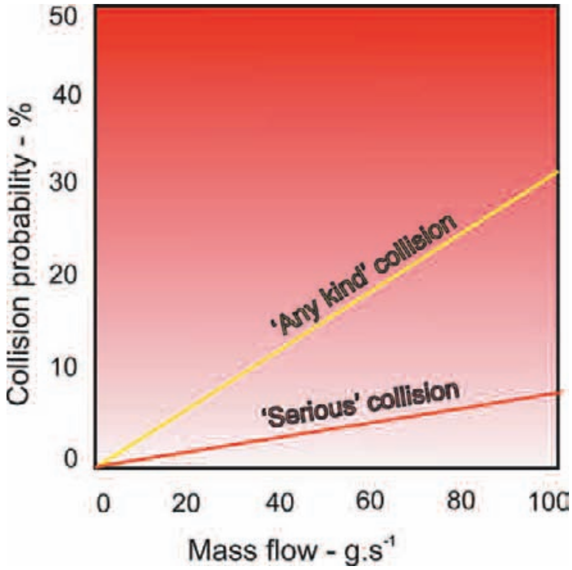

Fig.11 Effect of mass flow on collision probabilities – for specified shot stream parameters.

can be quantified to a reasonable degree of accuracy. Most of those properties require a knowledge of the shot stream's divergence angle. This angle is governed by the aspect ratio (length/diameter) and shape of the nozzle. There are hundreds of different nozzles available commercially - covering variations of shape, material and aspect ratio. Given the importance of shot nozzle divergence angle it is surprising that there is virtually no published information on the subject. Users appear to have to rely upon prior experience/guesswork to select an appropriate nozzle angle.

Control of all engineering processes is affected by parameter variability. During a given peening operation variations occur in mass flow rate, shot size, shot velocity and shot shape. The nozzle diameter, for example, increases progressively due to the severe wear regime. This, in turn, affects the shot stream's properties.

Quantified shot stream parameters can be employed to examine various aspects of shot peening. The one example given in this article, that of collision probabilities, has indicated that, with typical machine parameters, there is a significant chance of a 'serious collision' between inbound and outbound particles. Their combined velocities induce a much more critical shot fracture situation than that experienced by inbound particles contacting the component's surface. Colliding inbound particles are deflected away from the ideal perpendicular impact with the component's surface. Collision frequency and shot fracture rate can be reduced by lowering the shot feed rate (mass flow). This does, however, require longer peening times in order to achieve the same coverage. It is worth noting that 'excessive' peening not only wastes peening time and reduces component surface properties but also increases the total number of shot particle fractures.

Dr. David Kirk, our "Shot Peening Academic", is a regular contributor to The Shot Peener. Since his retirement, Dr. Kirk has been an Honorary Research Fellow at Coventry University, U.K. and is now a member of their Faculty of Engineering and Computing. We greatly appreciate his contribution to our publication.

Electronics Inc. Launches New Almen Strips

Electronics Inc. (EI), a manufacturer of products that control and improve shot peening processes, has announced the launch of their own brand of Almen strips.

EI now oversees every aspect of the manufacturing, grading and testing of their Almen strips. Before manufacturing their own Almen strips, EI purchased the strips from other sources and then graded and packaged the strips for re-sale.

Due to increased sales to the aerospace market, EI required improved quality control and larger inventories than available from suppliers. "Manufacturing Almen strips that meet aerospace specifications is a very demanding process," said Jack Champaigne, president of Electronics Inc. "We've been distributing Almen strips since 1987 and we have built a customer base that requires large inventories and tight quality control. We worked for several years on our own brand to make sure that every aspect of our strips exceeds our customers' needs," he added.

EI can provide strips to any specification—from standard MIL specifications to rigid aerospace specs—EI strips conform to width, height, thickness, flatness and hardness requirements. EI's Almen A, N or C strips are available in Grades 3, 2, 1, and 1-S[sm] and are pre-qualified and ready-to-use. Additional benefits of the new strips are due to EI's heat treatment process that provides improved control of hardness and flatness as well as eliminating the potential for decarburization.

The new strips are now being shipped worldwide and are in use in major aerospace facilities.

For more information, contact:
Tom Brickley
tom.brickley@electronics-inc.com
(574)256-5001 or 1-800-832-5653

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Battelle Offers Training Courses on Welded Structures

With the recent adoption of Battelle's Structural Stress Method in the recent 2007 ASME Div 2 Code and API 579/ASME FFS-1 Codes and Battelle's residual stress estimate techniques in the 2007 API 579/ASME FFS-1, Battelle is pleased to announce two unique training courses to be offered in Columbus, Ohio February 25 - 27:

Residual Stresses and Distortions in Welded Structures:
Modeling, Analysis, and Mitigation
February 25-26, 2008

The Mesh-Insensitive Structural Stress Method for Fatigue
Evaluation of Welded Structures
February 26-27, 2008

The courses will discuss the underlying basis supporting the Codes-adopted approaches and much more. Due to a space limitation, only the first 40 registrants will be admitted. Please register now by downloading a detailed course descriptions and a registration form at www.battelle.org/verity or calling Bonnie Bailey at 614-424-4388 or sending email to Baileyb@battelle.org.

Both courses will be taught by Dr. Pingsha Dong, Center for Welded Structures Research at Battelle. Dr. Dong has published over 180 peer-reviewed papers in archive journals and major conference proceedings and has lectured internationally as a keynote or invited speaker on fatigue/fracture of welded structures and advanced process computational modeling techniques for welding/joining processes. Headquartered in Columbus, Ohio, and established in 1929 as a nonprofit charitable trust, Battelle focuses on societal and economic impact and actively supports and promotes science and math education.

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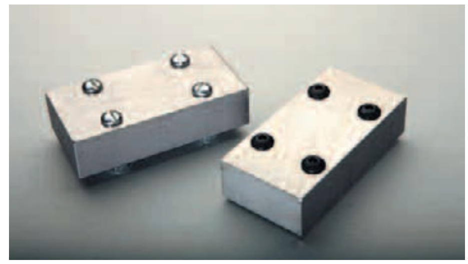
(Liquid form available only in the United States)



Almen Test Strip Holders

EI manufactures test strip holders in two designs: non-threaded or threaded.

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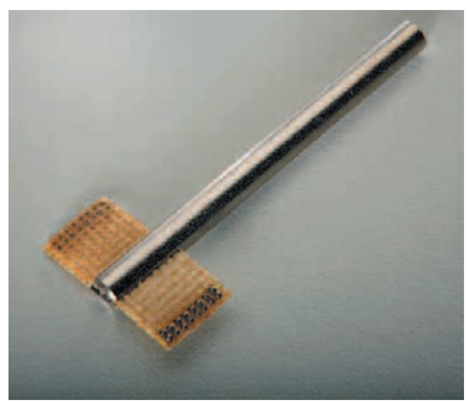

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Rösler Continues to Expand

Completion of a new 10,000 square-metre building for the construction of shot blast systems at Untermerzbach

Untermerzbach, Germany. *Over the past six months, Rösler Oberflächentechnik GmbH has invested Euro ten million in production halls in Germany for the design and manufacture of shot blast equipment and to accommodate Rösler's in-house steel fabrication business. The specialist in surface technology has therefore taken another step towards being less dependent on its suppliers; in future all fabrications and welded constructions for shot blast machines will be produced at the Untermerzbach site in a two-shift operation.*

Rösler's expansion activities have not stopped there. In January this year Baiker AG, Switzerland, a company specialising in shot blast technology that caters to the needs of the aviation and automobile industry, was integrated into the Rösler group. Rösler recently took over Reni Cirillo, an Italian producer of vibratory finishing machines that perfectly complement Rösler's range of products particularly in the Italian market. The Milan-based company will be integrated into the Rösler branch already established in Italy for many years.

Future success means investing in staff. Since the beginning of this year alone, 91 new jobs have been created at the German site, and in September another 19 apprentices started their vocational training in five different trades. Rösler currently employs approximately 1,130 staff (of which 66 are apprentices) at its two sites in Hausen and Untermerzbach, Germany as well as at its 13 branches worldwide. For more information on Rösler's products, contact them by Phone: +49 9533/924-0, Fax: +49 9533/924-300, E-mail: info@rosler.com, or visit their web site at www.rosler.com

Rösler will manufacture all welded constructions for their shot blasting machines at their expanded Untermerzbach facility.

strahlportal - A New German Engineering Company

Datteln, Germany. *In May 2007, Volker Schneidau launched strahlportal, a German engineering office for blast cleaning and shot peening applications. Mr. Schneidau, owner of the company, is an engineer with 10 years of advanced work experience in blast process reliability at SCHLICK and WHEELABRATOR.*

strahlportal is an engineering firm that gives consulting services and support in blast process development, process analysis and machine improvement, and supplies a German Internet portal with a knowledge base for shot blast technology. The knowledge base is free and can be reached at www.strahlwissen.de.

strahlportal provides shot peening control equipment but is independent from any machine manufacturer. Therefore Mr. Schneidau is free to develop the most efficient and economical blast cleaning and shot peening processes for the end users' benefit. Further, the consulting process can ensure that the machine purchase procedure includes the user's requirements, definition of specifications, support of the machine selection and operating cost control.

Volker Schneidau is the owner of strahlportal, a new engineering consulting firm.

The operating cost control gets more and more important as customers today are increasingly conscious of the TCO—total costs of ownership. In many cases, an unreliable and unadapted machine can easily generate higher operating costs in one or two years than the cost of a new machine, making the expected operating costs an important aspect for the decision-making process.

As the former wheelblast sales manager for SCHLICK and WHEELABRATOR in Germany, Mr. Schneidau has always worked with controlled blast cleaning and shot peening applications in international markets. "strahlportal and my work as a consultant is the ongoing dedication to these processes but with an independent view on the possible solutions," says the engineer.

strahportal, with Electronics Inc., will host a Shot Peening Workshop in Sinsheim, Germany, April 15-16, 2008.

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2007 U.S. Workshop
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Electronics Inc. recognized that something more was needed in the field of shot peening education—an advanced curriculum for engineers and managers that are responsible for the exciting new advanced technologies in our field. We were pleased to offer our Advanced Shot Peening Classes at the 2007 workshop and they were met with tremendous enthusiasm. Another indication that our field is moving forward was the large number of engineers and supervisors at the workshop. This indicates to me that shot peening is getting the recognition it deserves as a viable metal surface treatment because more decision-makers are educating themselves on its benefits. One of my favorite student comments from our workshop surveys summed it up nicely: "This was a great Workshop for a rookie like me. I am a Maintenance Super and learning more about the process makes me a better troubleshooter."

This workshop was also a time of reflection on how much the workshops mean to me personally. Dwight Lutsko with Lutsko Industrial Sales LLC presented me with a quilt made from nine t-shirts from past workshops (it's an EI workshop tradition to provide everyone with a specially-designed shirt). See the quilt in the photo below. Students, instructors and exhibitors signed it. You can't imagine how much I value this quilt—I feel privileged to be a part of this group.

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