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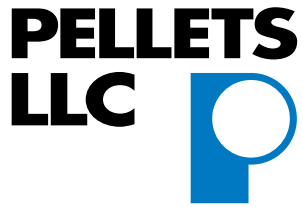
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Volume 20, Issue 4



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The Shot Peener

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The Shot Peener (ISSN 1069-2010), in print since 1986, is a quarterly publication from Electronics Incorporated with a circulation of over 5,000 readers worldwide. 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, joint efforts, 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 newsletter. 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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Plastic Media Blasting— Controlling the Process

by Dan Dickey, Innovative Peening Systems (IPS)

The most popular way to remove paint from an aircraft in the 1970's was to cover it with chemicals that would attack and swell the paint. The paint would then be removed by laborious methods such as rubbing and sanding. These methods created a hazardous stew of paint and toxic chemicals. Environmental regulations and the increased costs associated with handling and disposing of several thousand gallons of toxic waste for each aircraft became prohibitively time-consuming and expensive.

Another unrelated industry had a waste disposal challenge of a different nature. Button manufacturers were creating a waste by-product of buttonhole chads. I don't know who put buttonhole chads into a blast machine for aircraft paint stripping for the first time, but it certainly has evolved into a very large industry over the past 35 years. Button chads are no longer used as plastic blasting media but the media is still commonly made from a by-product of plastic items.

The uses for Plastic Media Blasting (PMB) are endless and more are being discovered every day. Traditional PMB is performed on coated flight surfaces such as airplane skins. Can you imagine using chemicals to strip the paint off of a C-5 military cargo plane or the delicate surfaces of the radar evasive B-2 bomber? The C-5 has 10,000 pounds of paint on the aircraft and the B-2 has many complex radar absorbing substrates. Economics dictate that a simple and effective method be used. Chemically stripping these aircraft is simply too expensive and environmentally unacceptable.

While PMB is cost-effective and environmentally-responsible, it's crucial to control the process so that it strips away tough paint and thermal-protection materials without damaging surfaces. Until recently, the PMB industry used subjective methods of inspecting the quality of the end result.

In 1994, Innovative Peening Systems built a state-of-the-art PMB facility for NASA at the Kennedy Space Center for stripping delicate space shuttle flight hardware such as the solid rocket boosters (SRB). The NASA paint-stripping operators developed a quality standard to establish the process with an aluminum coupon that was approximately two-foot-square and coated with a similar type of paint that was to be removed from the shuttle component. After machine setup, the operator would blast the coupon and then inspect it for surface roughness. If the blast stream was too aggressive, the coupon would exhibit severe surface roughness, indicating a dangerous blasting



As part of the quality control process, the PMB operators blast a two-foot-wide aluminum coupon that has been covered with a paint similar to the coating on the shuttle.



The Aero-Almen gage and aluminum strips provide a definitive measurement and quality control for the PMB process of the shuttles' solid rocket boosters.

condition. The challenge now was how to quantify and control this degree of blast intensity.

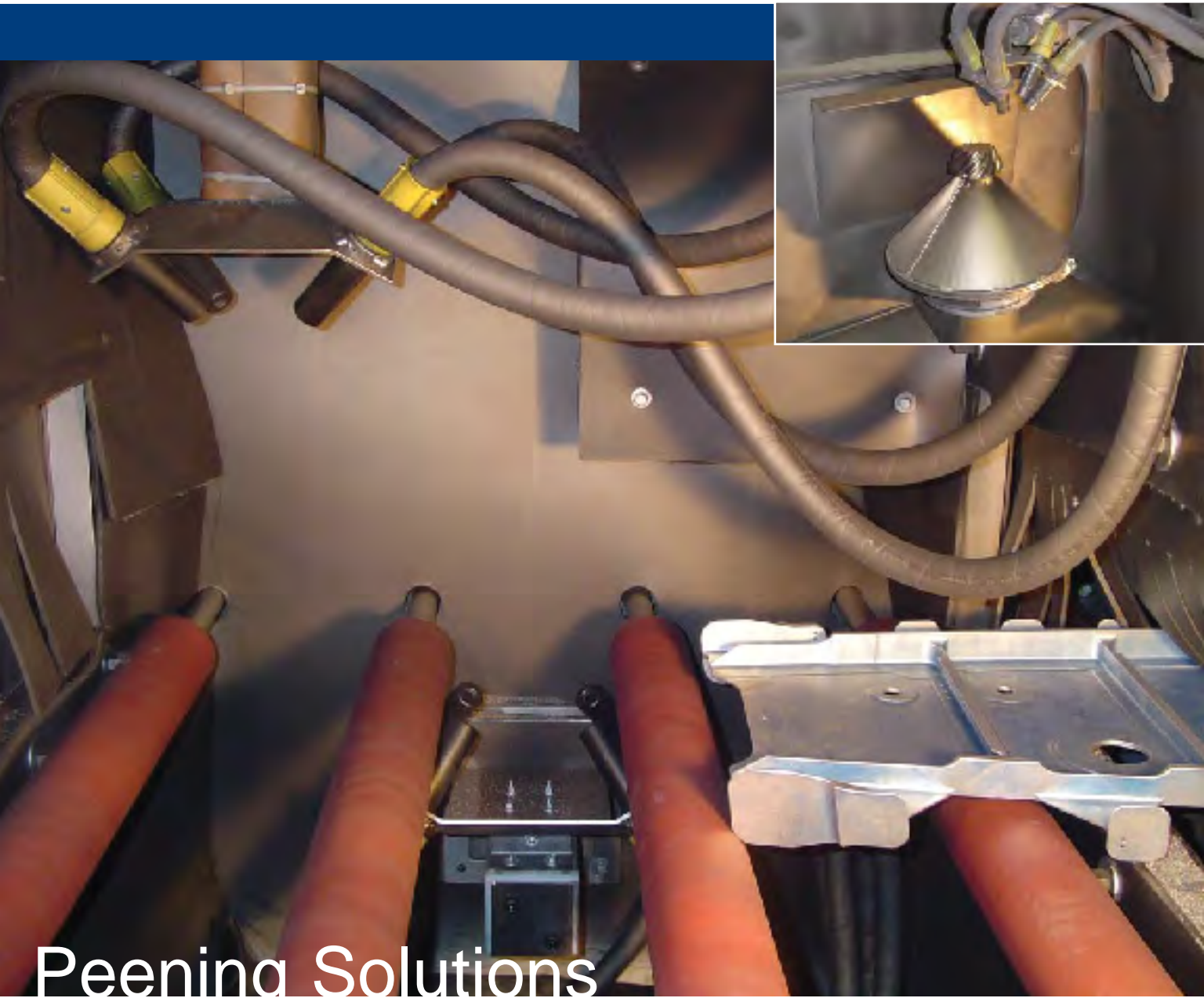
Does this sound familiar, Almen strip users? Well, it did to me, too. With some help from Electronics Incorporated, IPS presented a unique version of Almen test equipment, called the Aero-Almen gage, to the NASA staff. This gage is used in a similar manner to an Almen gage but it uses an aluminum strip called an Aero-Almen strip developed for the U.S. Air Force. Because the aluminum strip is not magnetic, it has to be held into place by a special hold-down block with four spring loaded fingers.

After we realized that this was a better method of testing, we decided that the Almen strip method of intensity determination could be included with the original coupon visual inspection test. This would allow us to limit the maximum "peening" intensity as established by Aero-Almen arc height. Several coated aluminum coupons were then subjected to the blast. The blast pressure was then turned up for each test until the coupon showed signs of excessive etching and was determined to be a rejected coupon. The Aero Almen strips were then subjected to the same blast parameters and a measurement was made to determine the new maximum intensity and arc height acceptable on an Aero-Almen strip.

Strips are now blasted with every piece of flight hardware and a specific measurement and each strip is logged for that part—we have a permanent record of quality that will follow the flight hardware during its lifetime. The benefit of this new quality procedure was immediately apparent. The Aero-Almen strip, measured on a precision gage, provides a definitive measurement thus providing excellent process control capability. ●



The shuttle's rocket booster nozzle inside the Innovative Peening Systems' PMB enclosure.



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Isotropic Mass Finishing for Surface Integrity and Part Performance

Authors are members of the SME-DESC Technical Group:
David A. Davidson, Deburring/Surface Finish Specialist;
Jack Clark, Applications Engineering Manager, ZYGO Corporation;
Dr. Michael L. Massarsky, President, Turbo-Finish Corporation

When presented with edge and surface finishing problems, many manufacturers continue to reach for solutions that rely on out-of-date, time-consuming and labor-intensive methods. It is still not unusual to see precision parts and critical hardware being manually handled and edge and surface finishing operations being performed with abrasive hand tools, or manually-controlled power tools that utilize coated abrasives or abrasive filaments. This situation often arises from insufficient planning and a lack of understanding on what will be required to render the manufactured part or component acceptable for consumer use or end-user application. At the root of the problem is a manufacturing and design engineering culture that considers its work done when the part comes off the machining center or the fabricating machine. Too often, part edge and surface condition is simply someone else's problem. In many cases not much thought is given to the problem until production is in full swing and parts start to fail quality assurance standards because they have burrs or undesirable surface conditions that not only affect function and performance but send costs through the roof.

This is a situation that deserves and is getting an increasing amount of scrutiny. It is a subject repeatedly discussed at the newly-formed "Deburring, Edge-Finish, and Surface Conditioning Technical Group" sponsored by the Society of Manufacturing Engineers in Dearborn, Michigan. At one of the group's monthly national teleconferences, Steven Alviti, a deburring and surface finish expert, summarized his experience this way:

"This group has been needed for a long time now. The sentiments expressed at the phone conference still hold true to this day. I face the same scenario time after time. The company develops a new product, they cost the product, they work out the productivity to decide what machinery they need to supply the demand, they spend \$500,000.00 - \$1,000,000.00 for CNC machinery, they get orders and start producing, they now have product to ship - but it has a burr! Now we get the call, after they have thrown five or six people at the cell with microscopes, exact-o-knives, files, sandpaper and worse, and have figured out that they are in a jam. Now we come up with a mechanical or automated solution, but it's like pulling teeth to have them spend \$10,000 or \$20,000 on a solution that should have been part of the initial phase. Whatever this group can do to bring mass finishing into the initial stages of engineering will be a benefit to all involved."

The costs of neglecting to consider deburring and surface conditioning in production planning and engineering can be - and often is - substantial. Frequently overlooked however, are the potentially serious problems that can develop from the ad hoc and interim solutions that are selected to deal with what now has become a manufacturing crisis. The manufacturers who resort to hand or manual finishing do not do so because of its cost. On a per piece basis, it is by far the most costly method of handling the problem - but often it is the most obvious solution and the easiest and the quickest to implement. Hiring some less-skilled temporary employees, and arming them with hand tools to attack the problem, may not be very imaginative, but it is certainly much less strenuous from an engineering perspective than approaching the

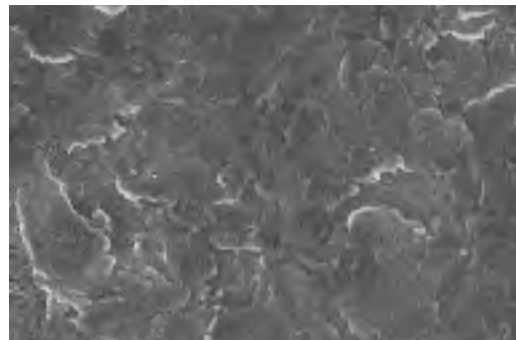


Figure 1. (Before) This photograph was taken with an electron microscope at 500x magnification. It shows the surface of a raw unfinished "as cast" turbine blade. The rough initial surface finish as measured by profilometer was in the 75 - 90 Ra (μin) range. As is typical of most cast, ground, turned, milled, EDM and forged surfaces, this surface shows a positive $R_s k$ [$R_s k$ - skewness - the measure of surface symmetry about the mean line of a profilometer graph. Unfinished parts usually display a heavy concentration of surface peaks above this mean line, generally considered to be an undesirable surface finish characteristic from a functional viewpoint.]



Figure 2. (After) This SEM photomicrograph (500X magnification) was taken after processing the same turbine blade in a multi-step procedure utilizing centrifugal barrel methods with both grinding and polishing free abrasive materials in sequence. The surface profile has been reduced from the original 75 - 90 Ra (μin) to a 5-9 Ra (μin) range. Additionally, there has been a plateauing of the surface and the resultant smoother surface manifests a negative skew ($R_s k$) instead of a positive skew. This type of surface is considered to be very "functional" in both the fluid and aerodynamic sense. The smooth, less turbulent flow created by this type of surface is preferred in many aerodynamic, automotive and other high force loading applications. Another important consideration the photomicrographs indicate is that surface and sub-surface fractures seem to have been removed. Observations with backscatter emission with a scanning electron microscope (SEM) gave no indication of residual fractures.

budgetary, capital asset acquisition and purchasing processes for something as mundane as deburring and surface finishing equipment. The reason this problem persists into the 21st century is that there is a very imperfect understanding of the hidden and more serious cost this manual and uncontrolled approach imposes.

The first casualty of this manual approach is the investment the manufacturer has made, often in the millions, for precise and computer controlled manufacturing equipment. The idea behind this investment was to have the ability to produce parts that are uniformly and carefully manufactured to exacting specifications and tolerances. At this point, in too many cases, the parts are then handed off to manual deburring and finishing procedures that will guarantee that no two parts will ever be alike.

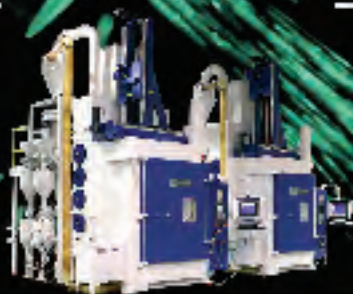
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Moreover, the increased complexity and precision requirements of mechanical products have reinforced the need for accurately producing and controlling the surface finish of manufactured parts. Variations in the surface texture can influence a variety of performance characteristics. The surface finish can affect the ability of the part to resist wear and fatigue, to assist or destroy effective lubrication, to increase or decrease friction and/or abrasion with cooperating parts, and to resist corrosion. As these characteristics become critical under certain operating conditions, the surface finish can dictate the performance, integrity and service life of the component.

The role of mass finishing processes (barrel, vibratory and centrifugal finishing) as a method for removal of burrs, developing edge contour and smoothing and polishing parts, has been well established and documented for many years. These processes have been used in a wide variety of part applications to promote safer part handling (by attenuation of sharp part edges) improve the fit and function of parts when assembled, and produce smooth, even micro-finished surfaces to meet either functional or aesthetic criteria or specifications. Processes for developing specific edge and/or surface profile conditions on parts in bulk are used in industries as diverse as the jewelry, dental and medical implant industries on up through the automotive and aerospace industries. Less well known and less clearly understood is the role specialized variants of these types of processes can play in extending the service life and performance of critical support components or tools in demanding manufacturing or operational applications.

Industry has always been looking to improve surface condition to enhance part performance, and this technology has become much better understood in recent years. Processes are routinely utilized to specifically improve life of parts and tools subject to failure from fatigue and to improve their performance. These improvements are mainly achieved by enhancing part surface texture in a number of different, and sometimes complimentary, ways.

To understand how micro-surface topography improvement can impact part performance, some understanding is required of how part surfaces developed from common machining, grinding and other methods can negatively influence part function over time. The following factors are involved.

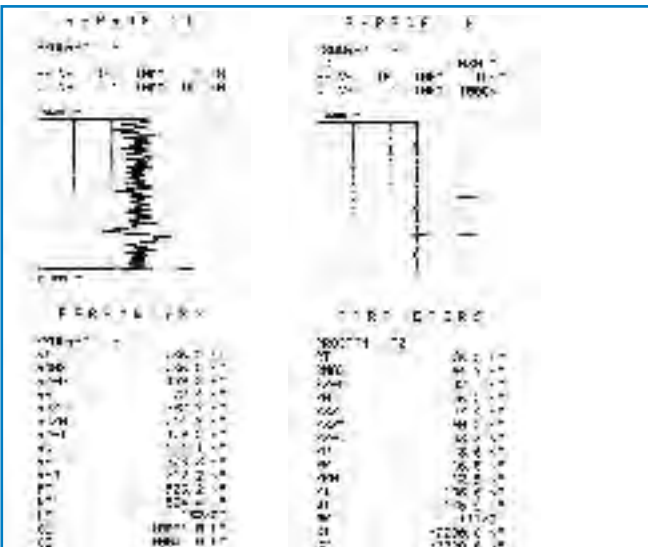


Figure 3. These profilometer graphs graphically illustrate in 2-D the difference between an as-cast positively skewed surface, and the same typical surface processed with a sequence of high energy loose media operations to produce an improved surface topology that is potentially very useful for mission critical components that require improved wear, fracture or fatigue resistance.

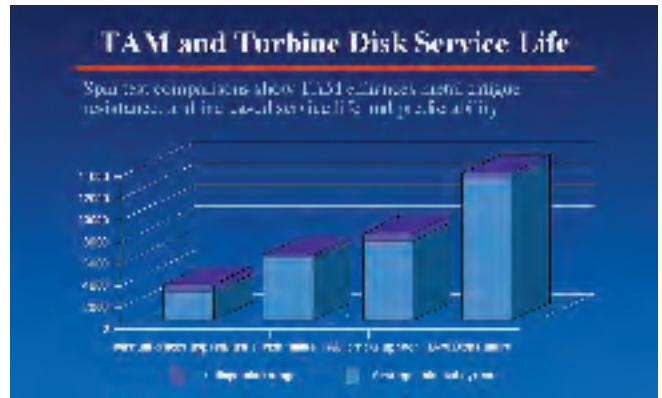


Figure 4. Edge and surface condition can produce dramatic improvements in performance and service life as this comparison between manually deburred and mechanically edge-contoured parts demonstrates. The Turbo-Finish method also develops compressive stress and stress equilibrium in large critical rotating components. Courtesy of Turbo-Finish Corporation

Positive vs. Negative Surface Skewness. The skew of surface profile symmetry can be an important surface attribute. Surfaces are typically characterized as being either negatively or positively skewed.

This surface characteristic is referred to as R_{sk} (R_{sk} – skewness – the measure of surface symmetry about the mean line of a profilometer graph). Unfinished parts usually display a heavy concentration of surface peaks above this mean line (a positive skew). It is axiomatic that almost all surfaces produced by common machining and fabrication methods are positively skewed. These positively skewed surfaces have an undesirable effect on the bearing ratio of surfaces, negatively impacting the performance of parts involved in applications where there is substantial surface-to-surface contact. Specialized high energy finishing procedures can truncate these surface profile peaks and achieve negatively skewed surfaces that are plateaued, presenting a much higher surface bearing contact area. Anecdotal evidence confirms that surface finishing procedures tailored to develop specific surface conditions with this in mind can have a dramatic impact on part life. In one example the life of tooling used in aluminum can stamping operations was extended 1000% or more by improved surface textures produced by mechanical surface treatment.

Directionalized vs. Random (Isotropic) Surface Texture Patterns. Somewhat related to surface texture skewness in importance is the directional nature of surface textures developed by typical machining and grinding methods. These machined surfaces are characterized by tool marks or grinding patterns that are aligned and directional in nature. It has been established that tool or part life and performance can be substantially enhanced if these types of surface textures can be altered into one that is more random in nature. Post-machining processes that utilize free or loose abrasive materials in a high energy context can alter the machined surface texture substantially, not only reducing surface peaks, but generating a surface in which the positioning of the peaks has been altered appreciably. These “isotropic” surface effects have been demonstrated to improve part wear and fracture resistance, bearing ratio and improve fatigue resistance.

Residual Tensile Stress vs. Residual Compressive Stress. Many machining and grinding processes tend to develop residual tensile stresses in the surface area of parts. These residual tensile stresses make parts susceptible to premature fracture and failure when repeatedly stressed. Certain high-energy mass finishing processes can be implemented to modify this surface stress condition, and replace it with uniform residual compressive stresses. Many manufacturers have discovered that as mass finishing processes

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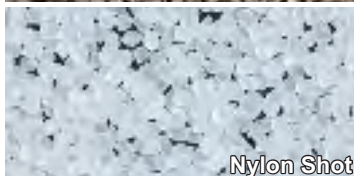
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have been adopted, put into service, and the parts involved have developed a working track record, an unanticipated development has taken place. Their parts are better—and not just in the sense that they no longer have burrs, sharp edges or that they have smoother surfaces. Depending on the application, they last longer in service, are less prone to metal fatigue failure, exhibit better tribological properties (translation: less friction and better wear resistance) and from a quality assurance perspective, are much more predictably consistent and uniform. The question that comes up is why do commonly used mass media finishing techniques produce this effect? There are several reasons. The methods typically are non-selective in nature. Edge and surface features of the part are processed identically and simultaneously. Additionally, they consistently develop beneficial compressive stress equilibriums.

These alterations in surface characteristics often improve part performance, service life and functionality in ways not clearly understood when the processes were adopted. In many applications, the uniformity and equilibrium of the edge and surface effects obtained have produced quality and performance advantages for critical parts that can far outweigh the substantial cost-reduction benefits that were the driving force behind the initial process implementation.

This assertion has been affirmed by both practical production experience and validation by experiment in laboratory settings. David Gane and his colleagues at Boeing have been studying the effects of using a combination of fixtured-part vibratory deburring and vibratory burnishing (referred to by them as “Vibro-peening” or “Vibro-strengthening”) processes to produce (1) sophisticated edge and surface finish values and (2) beneficial compressive stress to enhance metal fatigue resistance. In life cycle fatigue testing on titanium test coupons, it was determined that the vibro-deburring/burnishing

Continued on page 12



Figure 5. Centrifugal barrel machines such as these can produce exceptional edge and surface finishes in very short cycle times. Accelerated process effects can be developed because of the high speed interaction between abrasive media and part surfaces, and because media interaction with parts are characterized by high pressure by virtue of the high

centrifugal forces developed in the processes. Smaller turbine blades can be processed in the 5 x 8 inch compartments in the 12-liter capacity machine shown to the right. Larger centrifugal machines such as the 220 liter or 330 liter capacity machine shown to the left can handle much larger parts as the barrel compartments are as much as 42 inches in length. Larger parts processed in this type of machinery can be processed one at a time within the barrel compartment suspended within the media mass or be fixtured. Barrel compartments can be divided into processing segments to accommodate more than one part.

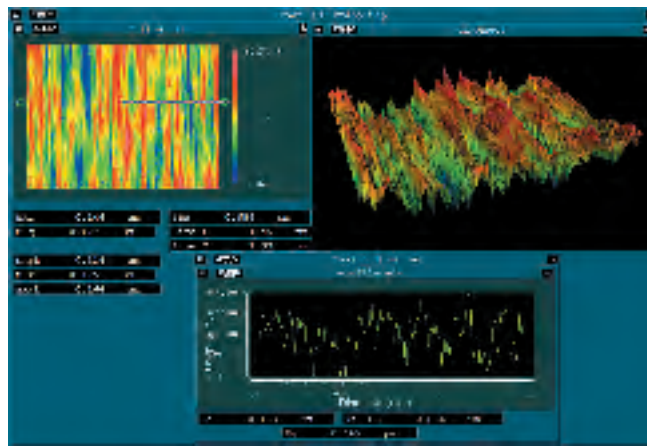
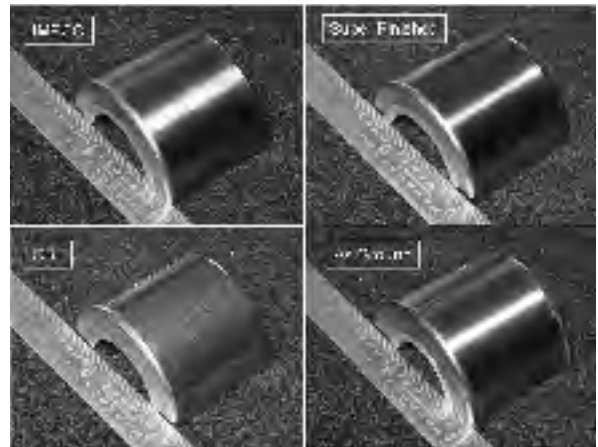


Figure 6. Increasingly sophisticated measurement methods are now utilized to characterize surface textures so that a more accurate correlation between surface texture and its possible effect on ultimate part performance and longevity can be drawn. Especially useful is the 3-D surface texture characterization, such as the one shown in the upper right hand graphic of this grouping. Optical interferometry and computer enhanced graphics make it possible to visualize potentially detrimental surface characteristics in ways not previously possible. The graphics shown are surface characterizations of a finely ground roller bearing. As the 3-D graphic clearly shows this is a dysfunctional surface, from both a wear resistance and a metal fatigue resistance perspective. In this case, both the predominant surface peaks and lack of isotropic (random surface texture pattern) are going to contribute to premature part failure and suboptimal performance. It should be understood that these types of surface characteristics are not necessarily the result of mistakes or errors, almost all common types of machining, grinding or fabrication methods produce surface characteristics of this nature. When correctly implemented, mass finishing processes are capable of correcting these inherent surface flaws by developing plateaued isotropic surfaces while simultaneously developing beneficial compressive stress and a stress equilibrium to the entire part. **Graphic courtesy of Jack Clark, Zygo Corporation.**

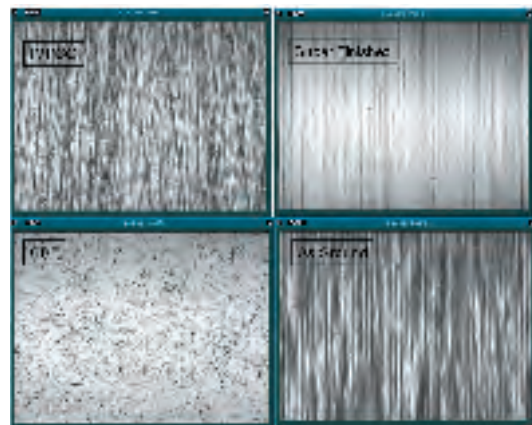


Figure 7. The 3-D color characterization shown in the earlier graphic in this series is based on a surface characterization of the “AS GROUND” photo and microphotograph shown here. The graphics in this set have been arranged for ease of comparison in terms of differentiating surface characteristics produced by various manufacturing methods. The lower left item of each set illustrates the type of surface developed from mass finishing methods (in this case centrifugal barrel finishing [CBF]) contrasted with grinding or machining methods. Clearly evident in the SEM (scanning electron microscope) microphotographs is the fact the centrifugal barrel process has been able to create a surface that has been plateaued (surface peaks and asperities have been leveled for much higher bearing load capabilities and reduced crack propagation) and is isotropic in nature (a non-directional surface pattern). These desirable surface characteristics have been developed concurrently with a highly advantageous stress equilibrium effect in a single process. **Photos courtesy of Jack Clark, Zygo Corporation.**

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method produced metal fatigue resistance that was comparable to high intensity peening that measured 17A with Almen strip measurements. The striking difference between the two methods however, is that the vibratory burnishing method produced the effect while retaining an overall surface roughness average of 1 μm (R_a), while surface finish values on the test coupon that had been processed with the 17A high intensity peening had climbed to values between 5-7 μm (R_a). The conclusion the authors reached in the study was that the practicality and economic feasibility of the vibro-deburring and burnishing method increased with part size and complexity.

Dr. Michael Massarsky of the Turbo-Finish Corporation was able to supply comparative measurements on parts processed by his method for edge and surface finish improvement. Utilizing this spindle oriented deburr and finish method it is possible to produce compressive stresses in the MPa = 300 - 600 range that formed to a surface layer of metal to a depth of 20 - 40 μm . Spin pit tests on turbine disk components processed with the method showed an improved cycle life of 13090 ± 450 cycles when compared to the test results for conventionally hand deburred disks of 5685 ± 335 cycles, a potential service life increase of 2 - 2.25 times, while reducing the dispersion range of cycles at which actual failure occurred. Vibratory tests on steel test coupons were also performed to determine improvements in metal fatigue resistance. The plate specimens were tested with vibratory amplitude of 0.52 mm, and load stress of 90 MPa. The destruction of specimens that had surface finishes developed by the Turbo-Finish method took place after:

$$(3 - 3.75) * 10^4 \text{ cycles}$$

a significant improvement over tests performed on conventionally ground plates that started to fail after:

$$(1.1 - 1.5) * 10^4 \text{ cycles.}$$

SUMMARY:

Mass media finishing techniques (barrel, vibratory, centrifugal and spindle finish) can be used to improve part performance and service life, and these processes can be tailored or modified to amplify this effect. Although the ability of these processes to drive down deburring and surface finishing costs when compared to manual procedures is well known and documented, their ability to dramatically effect part performance and service life are not. This facet of edge and surface finish processing needs to be better understood and deserves closer study and documentation. Industry and public needs would be well served by consortium of partners at the industry, university and governmental agency levels capable of researching all aspects of surface texture and surface conditioning related to part functionality, performance and service life. At the time of this writing, possible FAA intervention bringing the use of manual deburring techniques on commercial aircraft engine components under closer control are apparently being considered.

ACKNOWLEDGEMENTS: The author wishes to acknowledge the technical assistance of the following members of the Society of Manufacturing Engineer's DESC Technical Group [Deburring, Edge-Finish, Surface Conditioning]. Dr. Michael Massarsky, Turbo-Finish Corporation; David H. Gane, Boeing; Edward F. Rossman Ph. D., Boeing; Jack Clark, ZYGO Corporation; LaRoux Gillespie, PE, CMfgE, Honeywell. Rodney Grover, Society of Manufacturing Engineers.

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Figure 8. This large power generation turbine blade was made utilizing 6-axis machining technology. Centrifugal barrel finishing technology was used to clear and blend in the milling cutter paths and then develop very refined and burnished isotropic surfaces in the foil area.



Figure 9. This large aircraft engine turbine disk has been processed with the Turbo-Finish method. This dry abrasive finishing method has been successful in bringing mass media finish economies to large complex rotationally oriented parts while simultaneously developing significant compressive stress. In addition to the uniform and consistent edge contours developed, the method also produces highly sophisticated isotropic surface finishes by radically altering the character of the as-machined or as-ground surface finish. PHOTO courtesy Dr. Michael L. Massarsky, Turbo-Finish Corporation



Figure 10. These titanium test coupons show a before and after example of mass finishing processes being used to blend in milling cutter paths. Transforming the positively skewed surface profiles of machined parts into parts with isotropic and negatively skewed surface characteristics can be an important element in any program where surface improvements are being developed to improve wear resistance and metal fatigue resistance on critical parts.

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KSA Develops New Automated Peen Forming for Wing Skins

by Axel Friese, KSA

Founded as a spin-off of the Institute of Metal Forming (IBF) at Aachen Technical University in December 1993, KSA (*Kugelstrahlzentrum Aachen*) is a German limited company which specialises in Automated Peen Forming (APF) solutions and robot-aided process automation for the aeronautic and aerospace industries. Most of the company's key personnel, including its CEO Dr. Frank Wüstefeld, came to the company from IBF, bringing with them invaluable knowledge of the latest research on shot peening and of new technological developments in the industry. The company's mission is to support customers worldwide in implementing automated shot peening processes. It has consciously adopted an "open" transparent business policy, providing customers with process documentation and unlimited access to all relevant peening and quality control data.



Ariane 5: KSA's 'launch' customer

APF launched as a contract peening service for Ariane 5. KSA has rapidly made a name for itself in the shot peening industry through its development and application of CNC-controlled software for peen forming. After a development and certification phase, the company achieved its commercial breakthrough in 1999/2000 when MT Aerospace AG placed substantial orders for tank segments for the European space

launcher Ariane 5. In 2001, KSA started operating its own machine for robot-aided peen forming at its site in Aachen. A second facility is a 7-axis, CNC-controlled machine located at the nearby university institute. The company has already peen formed more than 2000 aerospace panels on a contract basis in Aachen, notably for the Ariane space launcher and for Airbus aircraft.



APF of Ariane 5 tank segments, performed as a contract peening service

Implementing APF at Airbus site

A further breakthrough occurred when Airbus Germany needed final peen forming to be carried out to its new laser-welded fuselage panels for the A 380 and approached KSA as a potential partner in 2001. The peen forming process needed to be flexible enough to accommodate design changes and also had to be applicable to a wide range of panel sizes. Above all, it had to be automated and integrated directly into production in a 3-shift operation at the Airbus plant. After successfully completing a 9-month joint testing programme, KSA peen formed more than 100 qualification parts and serial shells in Aachen. At the same time, a large-scale peening machine was developed and built by a sub-contracted machine manufacturer. The machine was then installed at the Airbus plant in Nordenham, Germany in November 2003 and programmed by KSA to peen form 8 different types of fuselage shell. APF has proven to be such a reliable and efficient process that it has already been extended to other aircraft models such as the Airbus A 318, A 340 and the new A 350.

The implementation of APF at Airbus can be seen as a first benchmark for shot peen forming as a state-of-the-art industrial process, i.e. an entirely automated process which is fully integrated into the production chain, thus contributing effectively to the reduction of throughput times and to lower costs. KSA continues to work closely with Airbus and is

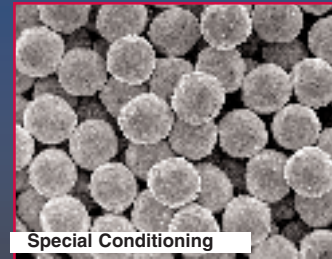
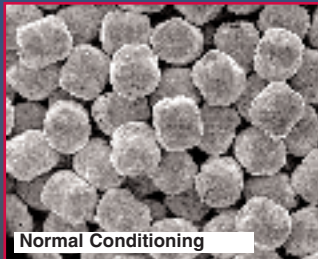
Continued in page 16

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Airbus A 380, reference for APF implementation at customer site

responsible for full APF support, including process development, system integration and service, program transfer, back-up capacities and so forth.

Co-operation with AeroSphere Inc. on APF4WINGS

With experience and know-how of this kind at its disposal, it was only logical that KSA should look for further applications of automated peen forming. A first contact between Frank Wüstefeld and the management staff of the Canadian company AeroSphere Inc. revealed a similar mindset with regard to the desirability of using automated peen forming for wing skins.

The AeroSphere Inc. team has many years of experience in the manual forming and fabrication of wing skins for corporate jets and regional aircrafts. They have participated in the development of over 15 different wing projects in collaboration with various aircraft OEMs. Their mission is to improve peen forming technology and to achieve higher repeatability and control standards. After an analysis of the technology available around the world, they concluded that KSA was the best company for a partnership. Not only was it already peen forming components with an excellent repeatability rate, it also had next-generation technology and a highly-qualified staff at its disposal, making it an ideal partner for developing new peen forming technology and extending it to aircraft wing forming. KSA and AeroSphere have now developed a detailed APF program based on AeroSphere's wing forming expertise and KSA's references for shot peening process control and automation (APF4WINGS).

"Now we are in a position to transfer our standard-setting APF to wing skin forming. Both aircraft OEMs and wing suppliers will profit from this situation," said Frank Wüstefeld.

AeroSphere believes that the manual peen forming process entails costly training and often results in serious health problems for the operators. According to AeroSphere, manual peen forming can, will and must be replaced—APF is the solution and an excellent value proposition to meet future aircraft design and fabrication standards.

First test programme on wing skin specimen

As of October 2006, the companies will work closely together on testing and perfecting the APF wing programme. This will initially take place in Aachen, where the process will be applied to small-scale wing skin specimen for corporate jets. Apart from the obvious advantages of APF4WINGS over manual peening such as control, efficiency, repeatability and reduced man-power dependency, the process will benefit from the latest shape-monitoring techniques and the possibility of using bigger shot of up to 10 mm / 0.39 inches. Bigger shot leads to improved surface conditions and reduces the need for sanding and surface finishing.

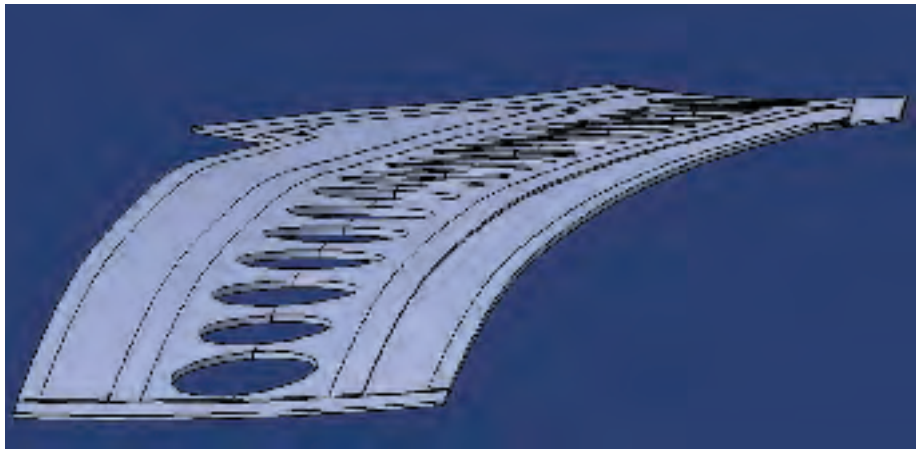
Following the first test phase, the intention is to use the knowledge and insight gained to apply APF to larger wing skins. As with the successful peen forming of fuselage panels on site for Airbus, it should be possible at a later date to integrate APF4WINGS directly into the production chain as a turn-key solution.

KSA has already worked very successfully with other partners to develop new peening. It has just completed a two-year trial phase at Rolls-Royce Germany to test its patented ISIC® - System (ISIC® = Integral Shot Intensity Control) for measuring shot velocity and distribution. By calibrating these values against Almen intensity, the system yields a computer-controlled measurement of shot intensity. The results of the two-year test period have been so convincing that Rolls-Royce Germany has now decided to integrate the ISIC® - System directly into its production process. KSA is extremely pleased about the successful development of this innovative technology, which is, incidentally, crucial for the inter-machine transferability of APF processes. The company is very optimistic that the exciting APF4WINGS proposition will be just as rewarding for the aircraft wing industry.

KSA is certified in accordance with the latest DIN EN ISO 9001 – 2000 and DIN EN 9100 for "Controlled Shot Peening" and "Automation Solutions". It also holds several patents related to process control and automated peen forming (APF).

For further information, please, contact:

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Shot Peening Solutions Save Prop Maker Money

by Herb Tobben

The Customer's Problem

A manufacturer of aircraft propellers was shot peening the shank, the portion of a propeller blade that mounts to the hub. The hub is the center section of the propeller, which carries the blades and is attached to the engine shaft. They shot peen the shank to maximize its fatigue life. It goes without saying that the propellers perform a function critical to the operation of the aircraft. Therefore, shot peening specifications must be followed precisely.

The company's production included three different sizes of propeller blade sets ranging in size from three feet to four feet in length. The aircraft manufacturer's specification called for shot peening to a specified intensity on the Almen-A strip. The propeller maker shot peened one size propeller at a time.

They were using an old cabinet, which had one oscillator and two blast guns, and their procedure called for a unique set-up for each size. That meant they needed to readjust the blast guns each time they changed from one propeller set to another. Setting the guns for each propeller set was critical as the customer had to be especially concerned about maintaining peening intensity. The old cabinet had no media flow control, necessitating painstaking attention to detail and testing for each set up. A shank that fails has catastrophic consequences.

The customer reported an estimated 400 hours per year on indirect labor changing from one set up to another.

The ZERO Solution

The ZERO automated solution was a special four feet by four feet by eight feet tall cabinet fabricated of 3/8-inch plate steel and rubber lined to withstand the barrage of steel shot. The cabinet has double opening doors in front for easy access to the cabinet interior for placing the parts on and removing them from the fixture.

The ZERO cabinet, sized to suit the range of parts, and painted a customer-specified color, incorporates special time-saving features. What differentiate this machine from its predecessor are its six guns, and simple but sophisticated controls. The cabinet has two oscillators and a total of six guns. Only two guns operate at a time; each set of two is appropriately positioned for a particular propeller set. So, simply by turning on each set of two guns and turning off the others, the set up is complete. Making this possible is at the heart of the new system, its PLC controls. They control the air to the guns, the media on-off from the shot gates that open and close to feed media to the guns, the oscillator speed, as well as the recovery equipment. And because the manufacturer's specification called for the steel shot to be gravity fed to the blast guns, the ZERO cabinet incorporates this out-of-the-ordinary feature. Since the PLC controls the set up for each of the three propeller sets, the changeover requires no other adjustment.

This cabinet not only saves the company 400 labor hours per year, but also eliminates the need for them to process larger-than-needed batches of product to reduce the labor cost associated with the changeover.

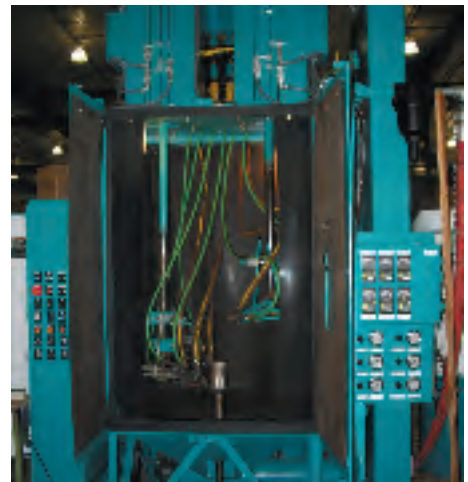
Operation of the ZERO cabinet is simple. For each propeller size, the appropriate fixture is put in place and the PLC is set to turn on and off the guns for the appropriate blast cycle for the particular size propeller blade. Controls also include a limit switch that controls the length of the oscillator stroke. The oscillator movement slows for the shot peening and has a rapid-traverse mechanism to return to the home position to minimize processing times. The cabinet also includes MagnaValve shot flow controllers, a vibratory classifier, and a level sensor with indicators for low-media and full conditions. These indicators prevent the system from running out of media and from overfilling the hopper.

Media recovery is handled with a screw conveyor and a bucket elevator to carry the shot to the top of the vibratory separator. From there the shot cascades through a two-screen vibratory classifier. And from there another bucket elevator refills the hopper, mounted above the cabinet for gravity feeding of the guns.

The vibratory classifier is especially critical to maintaining the proper operating mix to keeping the peening intensity within spec. The customer supplied their own dust collector. This new cabinet system significantly reduces indirect labor costs for the company and is easier to operate. Testing is minimized; now at prescribed intervals, the operator sends an Almen block through the cabinet and logs the results. With the cabinet's sophisticated controls, peening intensities are easier to maintain resulting in a more efficient and productive operation. ●



The customer processes various sizes of parts with unique fixtures and masking for each set up.



A flexible cabinet system—a PLC controls many functions, including the on-off cycle of the gravity-feed guns, the oscillator speed, and the media recovery.



Got a question about shot peening, abrasive blasting, or sample processing? Clemco can help. Call **Herb Tobben** at 1-636-239-8172 or submit your request at online at www.clemcoindustries.com in the Contact Us section. Herb Tobben is Sample Processing Manager for the ZERO Automation product line at Clemco Industries Corp. He is a regular speaker at the Electronics Inc Shot Peening Workshop.

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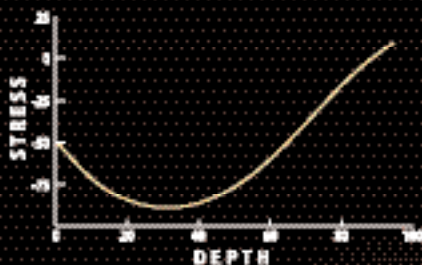


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Principles of Spiral Gravity Classification

by David Kirk

INTRODUCTION

Gravity separation of shot particles is of fundamental importance for peening. From a commercial viewpoint it is the basis of several methods for separating acceptable from unacceptable shot shapes i.e. classification. The commonest such method is probably spiral gravity separation. This method has a long and successful history and is used in a number of industries on a variety of particle types.

In use, shot particles can either fracture or wear. Fracture is the primary cause of a particle adopting an unacceptable shape. Wear, on the other hand, tends to improve the shape of particles – conditioning of cut steel wire being a classic example. The primary objective, therefore, is to separate broken particles from unbroken particles.

The fundamental principles of spiral gravity separation are analyzed in this paper. Fig.1 illustrates the essence of the situation. A sphere placed on a downward slope gains a rolling forward velocity. The downward slope is also inclined towards the central axis so that an inward force, F_{INWARD} , acts on the rolling particle.

This gravitational force increases with the slope angle, β . An opposing outward centrifugal force, $F_{OUTWARD}$, acts on the sphere. The centrifugal force increases with the square of the forward rolling velocity. If the outward force is greater than the inward force then the sphere will move outwards on the path shown. The dotted line indicates a constant track of radius R which would be followed if the two forces remained equal to one another.

This article analyses the geometrical and physical features of spiral gravity separation. Several simplifying assumptions are used in order to keep the applied mathematics at a digestible level. The motion of even a single particle pulled by gravity down a spiral slope is difficult to analyze, especially if the particle can have an

arbitrary shape. Friction and energy losses further complicate the picture. Millions of particles are involved during spiral gravity separation. The analysis presented here does, however, allow quantitative assessments to be made of the classification process.

GRAVITATIONAL ACCELERATION DOWN A FLAT SLOPE

Spherical and near-spherical shot particles will roll down a steep slope at an increasing velocity under the action of gravity. Particles that can be classed as being unacceptable will tumble down a slope and can achieve a substantial forward velocity.

(a) Rolling

Fig.2 is an illustration of a sphere which generates increasing forward and rotational velocities as it rolls down a steep slope whose angle is α . The acceleration, a , is related to gravitational acceleration, g , by the relationship that:

$$a = S.g.\sin\alpha \quad (1)$$

where S is the shape factor for the rolling body, having a value of $5/7$ for a perfect sphere and having lower values for any other shape.

$2/7$ corresponds to the fraction required to generate rotational energy.

The particle's forward velocity, v , increases with the distance travelled, s , under constant acceleration. For a particle starting at rest the governing equation is that:

$$v^2 = 2.a.s \quad (2)$$

Substituting the value of a from equation (1) into (2) yields the important equation:

$$v^2 = 2.S.g.\sin\alpha.s \quad (3)$$

The time, t , that a sphere takes to roll a given distance is given by:

$$t = 2s/v \quad (4)$$

(b) Tumbling

Tumbling motion depends on the precise shape of the particle, slope angle and on interaction with other particles. Stationary particles on a slope will be struck by another descending particles causing

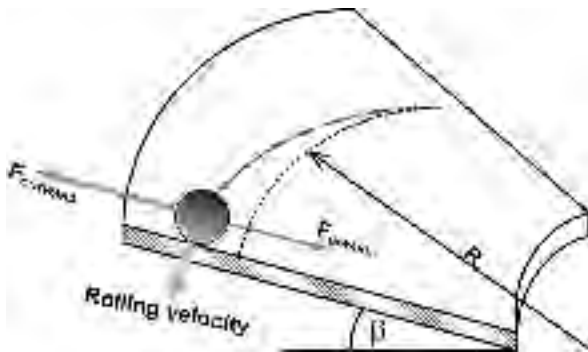


Fig.1 Section of spiral gravity separator showing major force elements.



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.

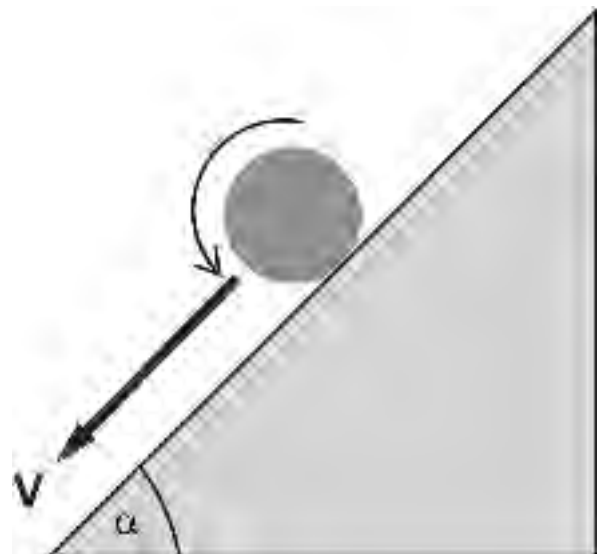


Fig.2 Sphere generating forward and rotational velocities.

Continued on page 26

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them to make further progression. All this makes the dynamics of the motion fiendishly complicated. Simple experiments can, however, determine the important characteristic features of tumbling motion. Consider, for example, a wooden plank inclined at predetermined angles (by leaning against a wall) together with a miscellaneous collection of irregular shapes. With the plank inclined at an angle of 45° every shape tumbles down the slope with increasing velocity. At an inclination of 20° none of the irregular shapes will move at all. For each shape there is a critical angle (“Angle of Repose”) above which tumbling will be initiated. A slightly more complicated experiment involves a hard plastic sheet supported along one edge. The weight and flexibility of the thin sheet yields a slope of decreasing angle – as shown in fig.3.

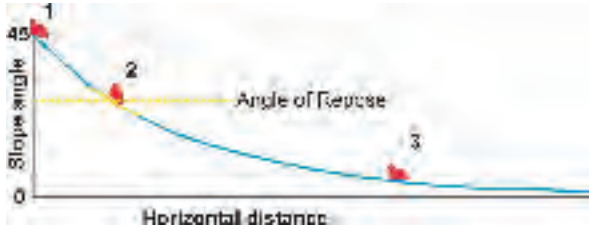


Fig.3 Irregular shape at various positions on a slope of decreasing angle.

An irregularly-shaped particle placed at position 1 will always tumble down the slope, but will slow down at low angles and come to rest at some position such as 3. Position 3 increases with increase in the size of the irregular particle – for a given shape. This effect is equivalent to the well-known general observation that ‘larger rocks fall further than smaller rocks’. When initially placed at position 2, however, the particle remains stationary – the corresponding angle generally being called the “angle of repose”.

GEOMETRY OF SPIRAL SEPARATORS

Fig.4 illustrates the magnitude of the problem that has to be addressed when considering the geometry of industrial spiral gravity separators. The characteristic features are a steep downward slope where the helix is attached to a central vertical column and a much shallower slope at the edge of the helix. For the separator shown, there are five concentric ‘left-handed’ helix slopes which are fed with shot independently.

One effective way of gaining a quantitative insight into spiral separator geometry is to consider the construction of a simple model separator. All that is needed is a cardboard disc, with a hole, glue and a vertical tube. Fig.5 shows the required shape of the disc.

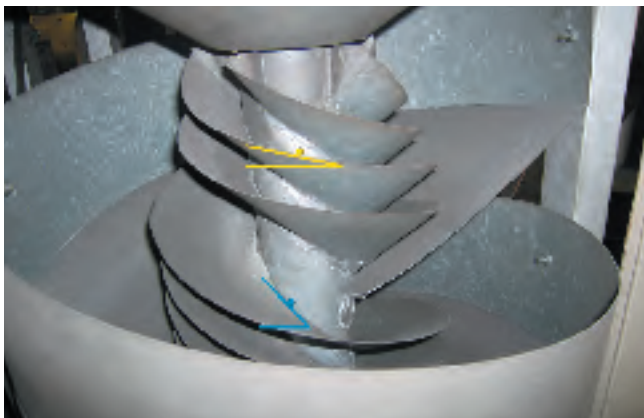


Fig.4 Photograph showing steep inner and shallow outer slopes of a spiral gravity separator.

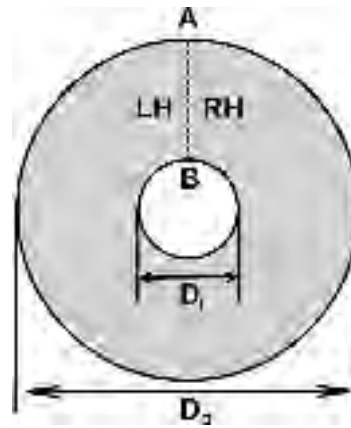


Fig.5 Disc element of simple spiral separator with cut to be made along AB.

Having made the cut along AB if we lift up the right-hand edge relative to the left-hand edge we have generated a ‘right-handed’ helix. The term ‘right-handed’ comes from the similarity with a screw that progresses inwards if turned clockwise by a right-handed person. Conversely lifting up the left-hand edge generates a ‘left-handed’ helix. As we continue to displace the edges the inner diameter, D_1 , decreases until it grips a vertical tube of diameter D along a helical path, see fig.6. The cardboard helix can then be glued in position to complete the model.

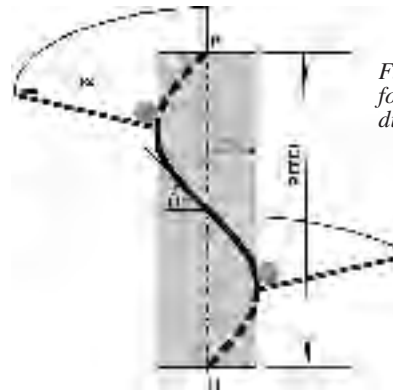


Fig.6 Left-handed helix formed around a cylinder of diameter, D .

Quantification of the parameters involved in spiral separator geometry only requires the application of basic mathematics. The helical path, P-H, shown in fig.6 is the hypotenuse of a right-angled triangle, see fig.7. $AB^2 = AC^2 + BC^2$. If the required slope angle α is to be 45° then the pitch has to be equal to the cylinder circumference i.e. $AC = BC$, so that $AB = AC\sqrt{2}$. Now the helical path length is the circumference of the hole shown in fig.5. Hence, for a 45° inner slope (see fig.4, blue angle), D_1 is given by $D\sqrt{2}$ where D is the diameter of the supporting cylinder shown in fig.6. The circumference $BC = \pi.D$ so that the pitch is then also $\pi.D$ and the helical path length is $\pi.D\sqrt{2}$.

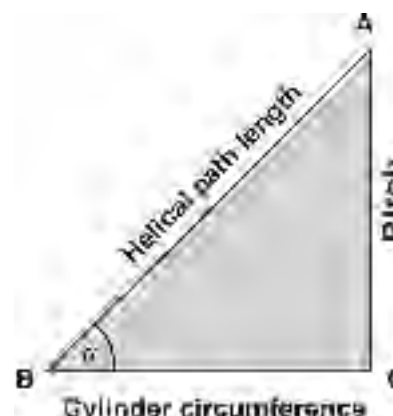


Fig.7 Helical path as the hypotenuse of triangle formed by required pitch and cylinder circumference.

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The outer edge of the sheet forms another helix with the much longer path length of $\pi \cdot D_0$ (see fig.5). This helix has a slope that depends on the magnitude of D_0 and the pitch. As an example if the cylinder diameter is 100mm, the formed spiral diameter is 500mm and a 45° inner slope is involved then the downward slope of the outer edge would be 11.3° (see fig.4, yellow angle). The formed spiral would also slope inwards towards the supporting cylinder. This is the important angle β of fig.1 and is given by:

$$\tan\beta = \frac{\pi \cdot D_1}{2(D_2 - D_1)} \quad (5)$$

where D_1 is the cylinder diameter and D_2 is the formed helix diameter.

For the previous example of $D_1 = 100\text{mm}$ and $D_2 = 500\text{mm}$ then $\beta = 21.4^\circ$.

Commercial separators usually have an added geometrical feature – a steady increase in the radius, r , of the formed helix – without affecting the steep downward slope adjacent to the supporting cylinder. The shape of the blanked-out sheet elements is then as shown in fig.8.

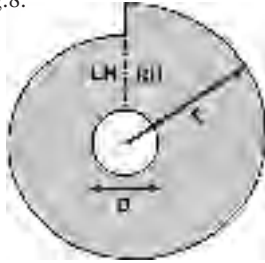


Fig.8 Variable radius, r , of helix element.

INWARD AND OUTWARD FORCES ON ROLLING SHOT PARTICLES

(a) Inward force

The inward force on a downward rolling shot particle is *constant* for a given inward slope angle, β . This force is called a “centripetal force” (because it acts inwards). Since force is equal to mass multiplied by acceleration we have that the centripetal force, C_p , is given by:

$$C_p = \text{mass} \cdot g \cdot \sin\beta \quad (6)$$

A steep inward angle, β is maintained for the first revolution of the helix spiral (see fig.4) in order to constrain the downward path of all shot particles to be around the centre cylinder. Thereafter the outer diameter of the spiral D_2 increases which decreases the value of β .

(b) Outward force

As rolling particles progress in a circular path around the central cylinder (as well as progressing downwards) they become subject to an outward centrifugal force, C_f . The corresponding outward acceleration is equal to v^2/r , where v is the particle’s forward velocity and r is the radius of the circular path. Rolling particles increase their velocity as they travel down the helix becoming subject to a rapidly increasing outwards force since:

$$C_f = \text{mass} \cdot v^2/r \quad (7)$$

(c) Net outward acceleration of rolling shot particles

Fig.9 indicates the opposing forces acting relative to a steep helix surface. The net force determines whether the particle will move outwards or whether it will move inwards. C_f acts perpendicular to the cylinder axis so that it has to be resolved along the surface in order to directly oppose C_p . The net force on the particle is therefore $C_f \cdot \cos\beta - C_p$. For large values of β the net force tends to be inwards.

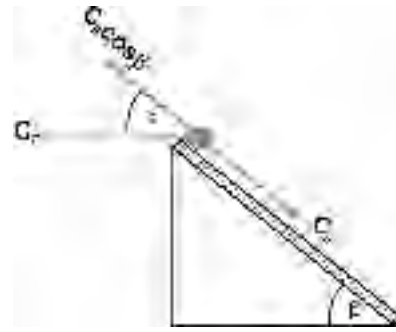


Fig.9 Radial forces acting on descending spherical particle.

The particle mass is the same for both forces. Hence, using equations (6) and (7), the net acceleration, a_{net} , becomes:

$$a_{\text{net}} = \cos\beta \cdot v^2/r - g \cdot \sin\beta \quad (8)$$

The effect of net radial acceleration on a descending, rolling, shot particle is illustrated in fig.10.

A particle on ‘section 1’ is subject to a large inward acceleration (shown as a red vector arrow) so that it is pressing against the support cylinder. As the particle generates downward velocity the consequential centrifugal force reduces the inward acceleration component so that when it reaches section 4 there is zero radial acceleration. Thereafter the net acceleration is outwards so that the particle moves further and further away from the support cylinder. At section 7 it has moved over the edge and is collected separately (from ‘reject’ particles).

TUMBLING REJECT PARTICLES

Particles that are destined to be rejected also generate substantial downward velocity. This, in turn, induces a centrifugal force. The crucial difference is that the downward acceleration is *rapidly* reduced to zero – because outward radial movement reduces the downward slope for the particle. As a consequence, irregular particles do not generate sufficient velocity, and therefore net radial acceleration, to move them outwards and over the edge of a helix. Hence, these ‘reject’ particles can be collected separately at the bottom of each helical slope.

As noted previously, large irregular particles tumble faster than small irregular particles. This characteristic is accommodated in commercial separators by using larger diameter helices for larger grades of shot. With larger diameters the average ‘ β angle’ is reduced and radial travel distances increased, providing greater obstacles for outward-moving, larger, irregular particles.



Fig.10 Schematic ‘tree’ of helix sections showing outward movement of a descending spherical shot particle.

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Fig.11 Cone distribution of shot to five separate spirals.

The output from the spiral separator consists of separate streams of acceptable and rejected shot particles. Fig.12 shows an example of output separation for a commercial unit.



Fig.12 Segregation of acceptable and rejected shot fractions.

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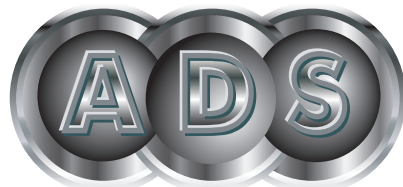
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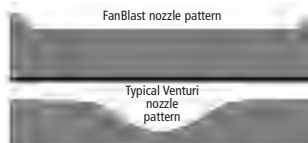


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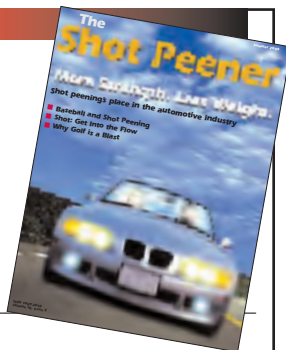


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Portland, Connecticut. Airex Rubber Products has been manufacturing precision molded, custom made rubber parts for customers worldwide since 1943. Our specialty is designing and manufacturing hard rubber masking for shot peening, vibratory finishing, glass bead peening, plating, plasma spraying (including HOVF), grit blasting, HA Coating and powder coating procedures.

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distance, p.s.i., media coarseness and temperature), our customers use the same masks for numerous cycles before they have to be replaced. The result is a distinct line of demarcation, no overspray and uniform finished parts. Airex also manufacture seals, boots, bellows, gaskets, extrusions (for part protection and media masking), plugs and other rubber products, and we are well experienced at rubber-to-metal bonding and rubber-to-non-metallic material bonding.

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For more information, contact Jim Hetrick by Phone: (860) 342-0850 ext. 304 or Email: jhetrick.airex@earthlink.net

Nadcap exceeds 2006 goal of 3,220 audits worldwide

The Performance Review Institute (PRI) announced that the 2006 target of 3,220 Nadcap audits has been exceeded. This is a great achievement and is indicative of the efficiency of the organisation and of the increasing worldwide recognition of the Nadcap brand. Perhaps one of the most important ingredients in the success of Nadcap is that subscribers feel it provides an absolute assurance that special process and product suppliers receive highly effective in-depth audits, while remaining cost-effective.

Dr. Chetan Daté of Honeywell Aerospace, Nadcap Management Council Chairperson, explained "The growing integration of Nadcap into the aerospace industry and its role in special process supplier management is indicative of the commitment to excellence throughout the global aerospace community."

The commitment of aerospace suppliers is not to be underestimated: the Supplier Support Committee (SSC) is active in encouraging suppliers to participate fully in the Nadcap program and reap the benefits of involvement. SSC Chairperson Dave Michaud of Fountain Plating confirmed: "The SSC supports all suppliers that are either Nadcap accredited or working towards achieving Nadcap accreditation. The primary way in which we do this is via supplier-focused sessions at the quarterly Nadcap meetings, which all suppliers are welcome to attend."

PRI has achieved this reputation by streamlining processes while maintaining high standards of service. One example of the cutting edge ethos of the organisation is the continuing enhancement of the audit-specific website, www.eAuditNet.com, which enables suppliers and subscribers online real time access to the accreditation process, as well as a Qualified Manufacturers List (QML) for quick reference.

To support the suppliers as they work towards Nadcap accreditation, PRI introduced the Nadcap Customer Support Initiative (NCSI) in 2004. Data for 2004-2005 shows that, on average, NCSI attendees incur 33% less major NCRs and 17% less minor NCRs during their initial audits than the overall average for the same period. In addition, it took NCSI attendees 37 supplier days to close out their audit, while the overall average for the same period was 47 supplier days to close out an audit. NCSI is a free web-based training program which assists suppliers in learning about the Nadcap system, enabling them to achieve accreditation more efficiently.

Arshad Hafeez, PRI Director of Global Business Operations, confirmed: "PRI is committed to efficiency and accessibility of information. The surpassing of the target of 3,220 audits at this stage is proof of the dedication of all Nadcap stakeholders to special process and product quality throughout the global aerospace industry."

Editor's Note: Learn more about PRI at their booth at the 2006 EI Shot Peening workshop in Indianapolis.

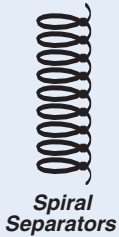
Pangborn® Corporation Wins Major Airblast System Installation Contract at Anniston Army Depot

Hagerstown, Maryland. Pangborn® Corporation, a leading global manufacturer of surface preparation equipment and service provider for the metals industry, has been awarded a major contract at Anniston Army Depot, Anniston, Alabama.

The contract calls for Pangborn to remove existing rooms, duct work and ventilation equipment. Structural modifications will be made to house three complete airblast rooms that will incorporate the latest airblast technology and ventilation equipment. Adherence to a completion schedule is important for the operation at Anniston. Pangborn® will have the system running in the 2nd quarter of 2007.

Pangborn Corporation, based in Hagerstown, MD. has led the way in all aspects of the surface preparation industry since its inception in 1904. From the design of equipment, to the services and products required to install, maintain and operate blast machines, Pangborn is positioned to continuously serve its customer base as it enters its second 100 years of operation.

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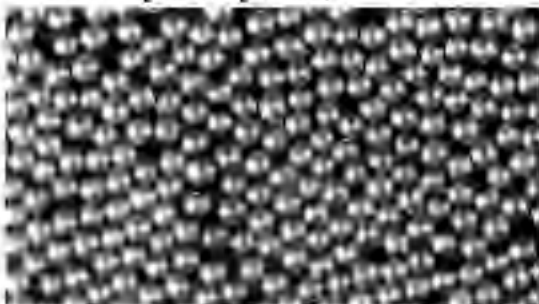
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The Parting Shot Jack Champaigne

Why a Picnic?

"How's business?" It's a question that is asked and answered with friends and colleagues everyday. From my viewpoint at EI, the answer is positive. As the world gets smaller due to leaps in technology and communication, quality products and responsible processes are more visible. We have found ourselves in a niche industry that is being refined, rediscovered and applied with new energy.

But it hasn't always been so easy for me. I ran my new business from my dining table in the early 1970s. My first significant client was Wheelabrator. Initially, I supplied their Air Pollution Control Division with controls for bag house and electrostatic precipitator dust collectors. It was 1978 before I was able to move into a small building and hire engineers and a production staff. At that point, I was building flow rate controls for Wheelabrator's 16-wheel peen forming machine for Boeing. That's how I discovered a unique and fascinating niche in the industry and the MagnaValve was born.

Wheelabrator has continued to be a significant contributor to our success and to many, many other companies and individuals. In employment opportunities alone, Wheelabrator provided jobs for 32 years in Mishawaka, Indiana. The Wheelabrator retirees club is still going strong in our community and we keep in touch with many of its members.

I'm at the point in my life where I have the time and inclination to reflect and I'm blessed to find myself having so much fun doing what I love. So why a picnic? EI is located on a beautiful property on the St. Joseph river and I saw a great opportunity to invite everyone that has ever worked at Wheelabrator to a picnic to celebrate and enjoy each other's company. Over 400 people joined us and we had a great time.

Everyone has a story like mine about a client or mentor that made a significant contribution to their success.

This picnic was my way to thank Wheelabrator for all they did for me and Electronics Inc. ●



Long-time friend Roger Johnson and me.



These are only a few of the picnic pictures; many more are online at www.electronics-inc.com. If you couldn't attend the picnic, visit the web site. You may spot old friends that you haven't seen in years.

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