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A Big Lift for the Aerospace Industry

Peening technology enables planes to fly lighter and longer.

By Robert B. Heaton, Director/Testing Laboratory, Empire Abrasive Equipment Co.; Jack Champaigne, President, Electronics Inc.; and John T. Cammett, Metals and Ceramics Branch Chief, Air 4.9.7.1, U.S. Naval Aviation Depot-Cherry Point

The daring knights of yore somehow stumbled upon peening as a method for saving their hides. Pounding a sword blade with a rounded hammer extended the life of the weapon and, no doubt, the life of its owner as well. To this day, peening has far-reaching safety consequences as manufacturers strive to produce stronger, lighter products, particularly in the fields of automobile and aircraft production.

Automobile manufacturers often peen defensively, meaning they fall back on the process to strengthen a spring, gear, connecting rod, anti-roll bar, or other component that fails prematurely. Because its products travel at higher altitudes, the aerospace industry takes a more proactive approach through the development of stringent peening specifications, in which adherence must frequently be documented.

Two primary factors drive aerospace's attention to peening details and documentation. For starters, a tight paper trail helps trace a potential part problem if a catastrophe occurs. Secondly, the industry relies heavily on shot peening technology to keep its products flying lighter and longer. Modern planes depend on the capability of shot peening to strengthen blades, roots, stators, gears, discs, combustion chambers, structural members, and many other parts too numerous to mention (Figure 1). Peening offers a big lift for the aerospace industry, but it must be tightly controlled to achieve anticipated performance gains.

Figure 1: Today's aircraft, both military and civilian, rely on the benefits of shot peening to fly lighter and longer.

Because rigorous control is central to peening effectiveness, shock waves reverberated throughout the aviation industry when three men associated with the St. Charles Metal Finishing Co. in St. Louis, were sentenced to jail terms in 1992 for falsifying inspection reports related to the peening of parts used in 1,000 fighter planes built by McDonnell Douglas Corp. As a consequence, the Pentagon delayed acceptance of F-15 Eagles, F/A-18 Hornets, and AV-88 Harriers, as well as Harpoon and Stand-off Land-attack missiles.

On civilian aircraft, off-spec or nonexistent shot peening has been cited as the cause of failures on parts ranging from engine shafts to landing gears. Recognizing the importance of sound peening practices, the FAA (U.S. Federal Aviation Administration) now assumes responsibility for educating its auditors and inspectors on shot peening and proper shot peening processes in airlines, job shops, and repair facilities. In fact, one of this article's authors (Champaigne) has been instrumental in developing shot peening training programs now attended regularly by FAA employees.

BENEFITS OF PEENING

Though peening can perform a variety of odd jobs, such as expanding undersized parts and improving oil retention, enhancing the fatigue strength of metals is its primary role. This cold-working process relies on the action of small spheres impacting metals at high velocities to create plastic deformation and resulting compressive-residual-stress distributions on and beneath metal surfaces. When used to optimal effect, peening delivers truly amazing results, in-cluding fatigue-life gains in components of 10 times or more, with no decrease in applied stress limits and/or increases in maximum stress tolerances up to 40% with no decrease in life.

Exploiting the full potential of peening in new applications, however, can involve a substantial amount of work.

Many factors—including shot size and type, coverage, intensity, and blast angles—must often be tested and optimized to attain the most productive relationship between the process and component performance and durability. Developing specifications to maximize shot peening benefits on components not previously peened requires the application of theory, history, and experiment, frequently involving destructive testing.

Figure 2: Modern Almen gauges provide precise readings of strip deflections used to measure peening intensity.

INTENSITY & COVERAGE STANDARDS

Although shot peening practitioners need not repeat the science supporting the specification, they better be on target, particularly in aerospace applications. Specifications for components as small as jet-engine turbine blades may run to many pages detailing masking requirements and separate treatments for roots and blades.

A device known as the Almen strip is central to most peening specifications, despite some recent reservations about the specific correlation between strip deflection and compressive residual stress. Developed by J.O. Almen of General Motors Research Laboratories in the 1940s, the Almen strip provides a method for measuring, specifying, and duplicating peening intensity. The concept is based on the premise that a thin, flat piece of metal, mounted on the surface of a solid block, will continue to arc convexly in proportion to the kinetic energy delivered by impacting shot and resulting deformation created until "saturation" is achieved. "Saturation" is defined as the earliest point on the arc height-exposure time curve, when doubling exposure times, produces an increase of 10% or less

Figure 3: Multiple blast nozzles provide processing flexibility by targeting different areas and facets of work surfaces.

Figure 4: An oscillating lance, which diverts shot direction sideways, peens the interiors of holes and recessed areas.

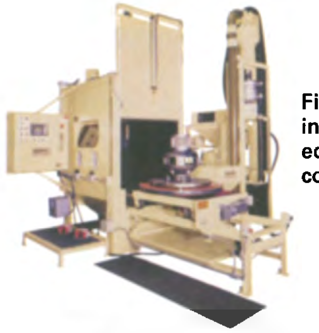


Figure 5: Programmable peening machine includes recycling equipment designed to assure consistent shot quality.

Figure 6: A stack of sieves, rotated and tapped automatically, segregate shot samples for inspection.

in arc height. To measure arc height, one places the peened Almen strip in an Almen gauge.

Modern Almen gauges (Figure 2) resolve to 0.0001 inch, thereby assuring sufficient accuracy and precision to properly measure arc heights from which Almen intensity is derived.

Figure 7: Programmable controls enable operators to designate processing procedures by simply inputting the appropriate part-identification number.

Figure 8: Equipment manufacturers employ test laboratories to experiment with various approaches for meeting customers' peening requirements at competitive costs.

INSPECTION METHODS

Traditionally, an inspector views the peened surface at magnification (10X to 30X) to assess coverage. Flat surfaces on softer metals are the easiest to inspect. Complex geometrical shapes or parts with holes, the most likely spots for underpeening and eventual cracking, present problems because of restricted visibility. Harder metals pose difficulties because of shallow indents, which may not be optically observable.

These challenges may be mitigated with the application of tracer coatings, which provide a colorful landscape of peening coverage. Computer analysis, using either contact or electromagnetic data, may be employed to minimize subjectivity.

In essence, the computer approach compares a desired surface profile with an actual profile obtained after peening to determine if results fall within acceptable coverage parameters.

PEENING EQUIPMENT

Peening equipment normally relies on either a mechanical or pneumatic system to propel shot.

Mechanical systems offer energy-saving advantages in mass production. Rotating wheels with blades impart momentum directly to the shot and are capable of delivering large volumes of media at high velocity. Accessory equipment must often accompany these systems to turn or roll workpieces because the shot stream is unidirectional. Also, "hot spot" adjustments may be required because these machines produce a wide pattern in comparison to their actual work focus.

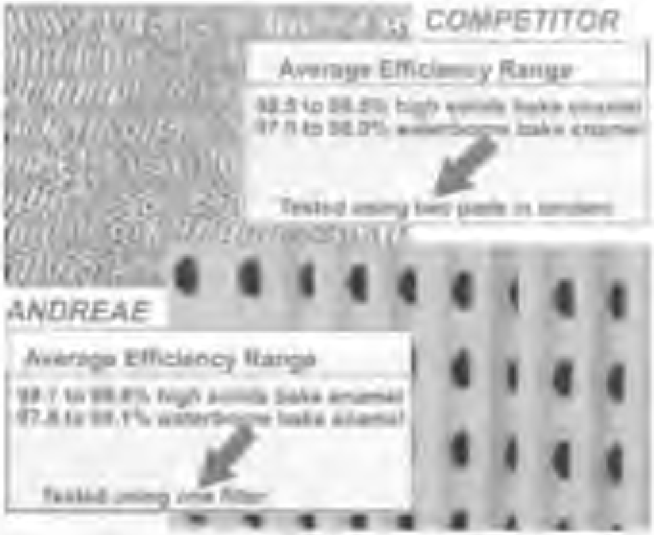
Controlling shot momentum, however, is a simple matter of selecting the desired wheel speed because the "thrown" shot maintains a relatively uniform velocity.

Pneumatic peening systems take two approaches, commonly known as "suction" and "pressure." The fundamental difference between the two is that a suction system relies on pressure differential created by moving compressed air to draw shot from an unpressurized storage hopper into a blast gun from which it is expelled onto the work surface. In a pressure system, the entire arrangement, including the shot-storage vessel, is pressurized. When actuated, the system feeds shot from the vessel into a pressurized feed line connected to blast nozzles, which focus shot on the work surface.

Pressure systems have the advantage of using compressed air more efficiently than suction systems while providing more precise control of shot velocities at both high and low operating pressures. Suction systems, on the other hand, simplify the use of multiple blast guns and are normally less expensive and easier to maintain.

In both cases, however, the ability to deploy multiple blast outlets (Figure 3) capable of tracing contoured surfaces gives pneumatic systems a major edge over mechanical systems in peening parts with complex geometrical contours and with reentrant indents or holes (Figure 4).

Regardless of the system selected, peening to specifications requires proper maintenance of peening-media quality. Besides reducing the size, depth, and shape of indentations, degraded shot may also cut or abrade the work surface, thereby reducing desired peening effects. Even the highest quality shot begins to break up after multiple impacts, at which point its remnants must be removed from the processing equipment. Most often this cleanup is accomplished



with a classification system (Figure 5) that maintains correct shot-size distribution and eliminates misshapen and broken media as well as debris and foreign objects.

The shot is also subjected to inspection for maintenance of shape and size according to specifications. The analysis is performed with a sample of 100 grams of shot placed into a stack of nested standard sieve screens that segregate the shot according to size.

The stack of sieves is rotated and tapped (Figure 6) automatically for 5 to 15 minutes after which the amount on each screen is weighed and compared to the specifications. The shape inspection is performed on a sample of media, usually in a half-inch square field with a stereo view at 10X to 30X magnification. Unacceptable shapes are counted and compared to specification values for acceptance or rejection of the media.

PROCESS CONTROLS

Peening can be controlled manually, automatically, or somewhere in between. Today, even the tightest specifications on a simple part can be achieved within the confines of a peening cabinet. By adding various accessories, such as nozzle oscillators, part fixtures, flow-control and monitoring devices, and programmable nozzle-motion controls, repeatability becomes an easily documented reality.

The growing versatility offered by increasingly effective programmable controls continues to draw more manufacturers and job shops toward peening in-house where they have a tighter grip on quality control. At the same time, producers of peening equipment are responding to demand by tailoring products to market needs. As a case in point, an FAA-certified repair center for jet-engine parts wanted to bring precision-peening work on disks and hubs in-house without stressing finances for new machinery.

Requirements for the peening system included automated features to control air pressure, media quality, shot-flow rate, processing times, and blast-nozzle movements, plus the ability to peen exterior slots and interior holes on components of various sizes. Other features, such as fault sensors, pressure regulators, flow monitors, and shot classifiers, were

implemented not only to assure tight quality control, but also to open avenues for the repair shop to accrue future, and possibly more demanding, new business. Because the machine was equipped with programmable controls (Figure 7), part changeovers could be accomplished in a matter of minutes once processing parameters had been established and stored in the controller.

BACK TO THE LAB

Aerospace peening specifications normally evolve from trial and error based on destructive tests, including mechanical testing and X-ray diffraction residual-stress measurement. As indicated previously, finding the right mix of peening parameters requires a lot of science. Aircraft designers continue to expand the envelope of "lighter, stronger, and longer" by exploiting the potential of shot peening to enhance component performance and durability.

Manufacturers of peening equipment also spend many hours in test facilities (Figure 9) to produce machinery capable of meeting production specifications. Often, equipment proposals alone require extensive testing with sample parts to develop reliable, cost-effective, and creative approaches that exploit the growing capabilities of programmable controls. Because this technology provides a reliable and flexible means for automating—and repeating—critical peening processes, it has been a boon to practitioners as well as those of us who rely on the benefits of peening every time we fly.

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Robert Heaton, during 30 years at Empire Abrasive Equipment Co., has contributed to the design of shot-peening systems and has worked closely with a number of major U.S. aircraft component manufacturers and airlines to develop peening specifications, operator training programs and automated peening systems. He currently directs laboratory operations at Empire. He can be contacted at (e-mail) rheaton@empire-airblast.com.

Jack Champaigne is president of Electronics Inc., a developer of control components used in shot-peening equipment. He has been instrumental in creating training courses for peening practitioners and FAA inspectors. He plays an active role on SAE committees for shot-peening specifications and is a member of the International Scientific Committee on Shot Peening. Champaigne can be contacted at (e-mail) jack.champaigne@electronics-inc.com.

John Cammett works with the U.S. Navy to analyze aircraft-component failures and develop remedial solutions. During 25 years with private companies, including General Electric, he studied many aspects of metal fatigue in aircraft engines. He is a past chairman and current member of ASM International. Cammett can be contacted at (e-mail) john.cammett@navy.mi. mf