Volume 5

Issue 4

THE SHOT PEENER

iter 1992

INTERNATIONAL NEWSLETTER FOR SHOT PEENING-SURFACE FINISHING INDUSTRY

IN THIS ISSUE

PRACTICAL APPLICATION OF SHOT PEENING

by Stephen Williams, VACU-BLAST LIMITED

This article considers the effects of shot peening on fatigue life improvement in some aerospace applications.

Shot peening is a cold working, surface conditioning process. The main objectives are to improve resistance to fatigue, stress corrosion cracking and surface wear.

The process employs a stream of spherical particles to bombard the surface of the component. The impact of each particle produces an indentation on the surface due to the plastic flow of material. This indentation has a larger surface area than the original surface and cumulatively the indentations try to produce a surface expansion.

The elastically deformed sub-surface layers try to resist this surface expansion, inducing a compressive stress at the surface balanced by a tensile stress of lower magnitude through the core of the material, as seen in Figure 1.

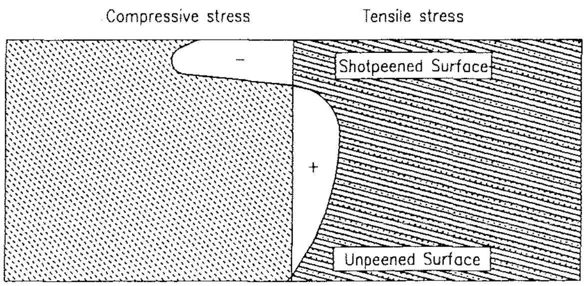

Figure 1 Stress distribution through the thickness of a component peened on one side.

The magnitude of the compressive stress is dependent upon the kinetic energy of the impacting particles, the yield strength of the component material and the relative hardness of the media and the component.

Two factors, mass and velocity, influence the kinetic energy of a particle in the following way.

$$E=1/2mv^2$$

That is, E = Kinetic energy (j), m = mass of particle (kg) and v = velocity of the particle (m/s). Example, machine marks, scratched, or sharp changes in section. Shot peening is less effective in preventing fatigue failures which initiate from defects present below the surface, for example, porosity (because the induced sub-surface tensile stresses can lead to sub-surface crack growth in these circumstances).

Overpeening can produce laps on the peened surface and in adverse environments lead to pockets of localized corrosion. It is generally accepted that overpeening is undesirable and potentially dangerous.

From the above it can be seen that machine designs, operator training and effective quality assurance are paramount to the safe exploitation of the process. Today these conditions are within our grasp.

The term peening intensity provides an indication of the impact energy transferred to the surface component. In practice the peening intensity is determined by representing the surface of a component with an Almen strip supported on an Almen block. The strip is peened on one side and when released from the Almen block, the compressive stress at the surface causes the strip to curve. This curvature is measured at the center of the strip on an Almen gauge and becomes the arc height.

The selection of strip thickness is dictated by the nature of the peening media and the intensities generated. Metallic and large non-metallic media generate large arc heights and require thicker strips. (Figure 2)

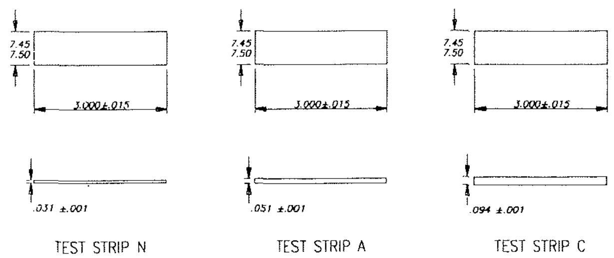

Figure 2 The size specification for Almen Strips.

Combinations of particle impact velocity, media flow rate and exposure time may produce the same arc height but varying benefits in fatigue resistance. It is essential that saturation is achieved at the desired arch height.

Saturation is the condition which exists in an Almen strip when doubling the time of exposure of a second strip gives an increase in arc height of less than 10 per cent of the original. (Figure 3)

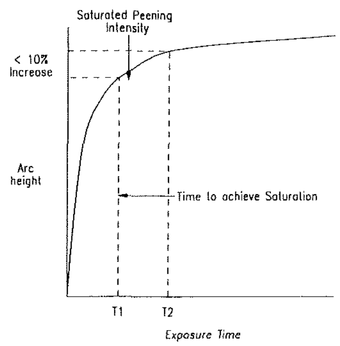

Figure 3 Typical Saturation Curve

It corresponds to a condition where the Almen strip has uniform stress distribution over the whole of the peened surface.

The conditions necessary to achieve the desired arc height at saturation are determined by tests. The arc height at saturation is the peening intensity.

Coverage is dependent upon the impact energy and number of particles, the hardness of the media, the Almen strip and the component. Coverage is determined by visual examination. Confusion can arise when the material of the component to be peened has different hardness to the Almen strip. The amount of plastic deformation in a material harder than that of the Almen strip will be less, resulting in smaller diameter indentations and possible incomplete coverage. It is essential that both the strip and component are examined for coverage which must be at least 100 per cent.

The peening intensity which gives optimum fatigue resistance is determined by subjecting specimens to accelerated fatigue testing. This must represent the type of stressing the component will be subjected to in service, for example, push-pull, three-point bend, four-point bend or rotation-bend. high stress levels will induce failure after fewer cycles, whereas alternating stress below a certain level will not cause failure. (Figure 4)

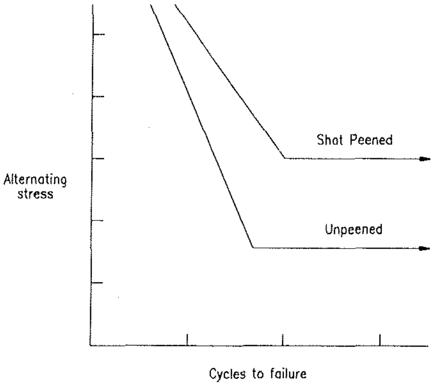

Figure 4 Typical improvements in fatigue resistance.

This threshold level of alternating stress is referred to as the fatigue limit of fatigue strength of the material.

Having determined the peening intensity required for improved fatigue resistance, the shot peening machine must be checked to ensure that the desired arch height is produced at saturation prior to shot peening any components. (Figure 5)

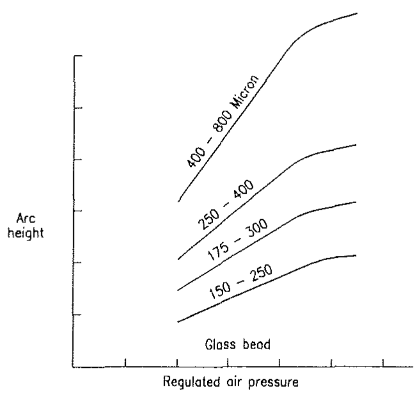

Figure 5 Typical arc heights attainable with different sizes of media

This check must be conducted at regular intervals when processing the large batches of components, or before and after processing components requiring long peening times. All peened areas of the component must be inspected for coverage.

Although steel shot of different sizes is the most common of peening media, there is an increase in the number of non-ferrous components being peened with glass and ceramic media.

Steel shot is manufactured from high carbon (1 per cent). Batches of shot are heat treated and tempered to a microstructure of tempered martensite which gives durability and resistance to fracture. Slight alterations in time and temperature produces shot of different hardnesses. All peening quality steel shot should be pre-conditioned prior to use and reclassified for size and shape.

Glass beads are manufactured from high grade glass with much combined silica. Glass bead peened surfaces have a satin finish.

Ceramic beads are manufactured by fusing a mixture of zirconium, silicon and aluminium oxides at a high temperature. These have good roundness and a smooth surface which produce a matt finish on the surface of the component.

Metallic media produces higher peening intensities than glass or ceramic media due to its higher density. However, glass and ceramic media have other advantages. They are chemically inert and leave no tra[illegible]of contamination even when peening soft aluminium alloys.

Once the type of media and particle size have been determined, the number of impacts per unit time and the particle velocity become the dominant factors in achieving intensity and coverage. The media flow rate can be controlled by servo-loop feed valves and monitored by the measurement of either the electrostatic charge of the particle or the capacitance of the flowing media.

Modern shot peening equipment (Figure 6) is now at such an advanced state that all the factors influencing peening intensity and coverage can be rigidly controlled to reproduce Almen intensities within ± 0.00025mm.

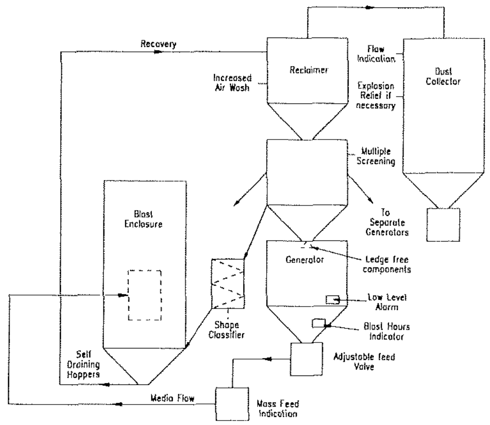

Figure 6 Flow diagram of a typical shot peening machine

This article is principally concerned with the use of compressed air to propel the peening media onto the surface of the component. Hov[illegible]r, there are other systems which utilise either a centrifugal wheel to p[illegible]el the media, a slurry pump where the media is held in a liquid suspension and ejected through a nozzle, or pure gravity where the media is simply dropped onto the component.

The air peen system is the most universally applied method to propel the peening media. A high pressure air supply accelerates the media through a nozzle which then impacts upon the surface of the component. There are three ways to introduce the media into the high pressure air stream. They are pressure feeding, suction feeding or gravity fed suction.

The most flexible system incorporates the pressure feeding technique. Media is stored in a vessel which is pressurized during operation. This media is metered through a feed valve situated beneath the vessel into the moving air stream. The air and media mixture is conveyed along a flexible blast hose to the nozzle and attains maximum velocity at the point where the air and particle speeds are equal.

By replacing the nozzle with a side outlet lance, a rotary head or deflector mechanism or both, the process can be applied to the internal bores of shafts, oil holes and other inaccessible areas of components. (Figure 7)

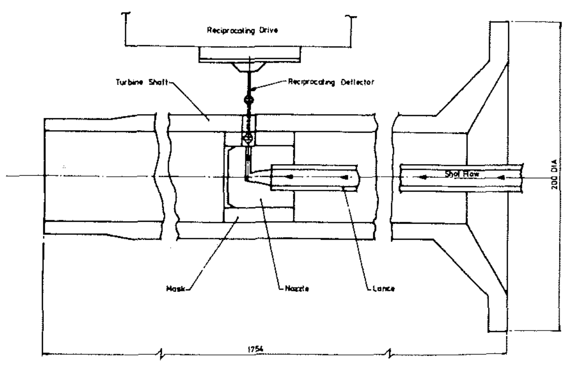

Figure 7 A system to shot peen the wall of oil holes in an aero engine turbine shaft

AIRBLAST SYSTEMS

All airblast systems allow multi-nozzle operation where each nozzle can be directed onto a particular area of a component. The nozzles can be independently selected as the manipulator passes over the specified area. (See Figure 8) Some components may require localized high intensity peening in areas of high stress concentration and lower intensity peening over the remainder of the component with media of different size. Almost instantaneous changes in media size can be accomplished by selecting media from a different pressure vessel or storage hopper.

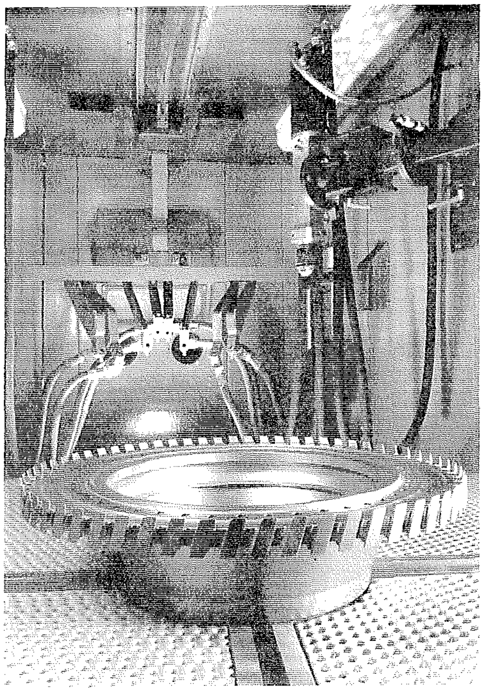

Figure 8 Airblast system

A test run must be conducted with the appropriate fixture where the Almen strips are arranged to represent the surfaces of the component to be peened. The Almen strips provide tangible evidence of the peening program's success which can then be applied to the component. The computer will ensure that all the parameters remain within defined limits during test and component runs. In the event of a parameter deviation, the process will cease and an alarm will indicate the fault. A quality decision then has to b e made to decide how to proceed.

The reclamation system built into shot peening equipment is of equal importance to the generation system, since it is essential that reusable media is separated from any debris or media not conforming to the original specification.

The reclamation system may utilise mechanical devices such as Archimedian screws, scrapers or bucket elevators to transfer the media from the bottom of the enclosure back to the generator. Pneumatic recovery systems overcome the problem of retained media always encountered in mechanical systems. A fan is used to generate the recovery airflow. (Figure 9)

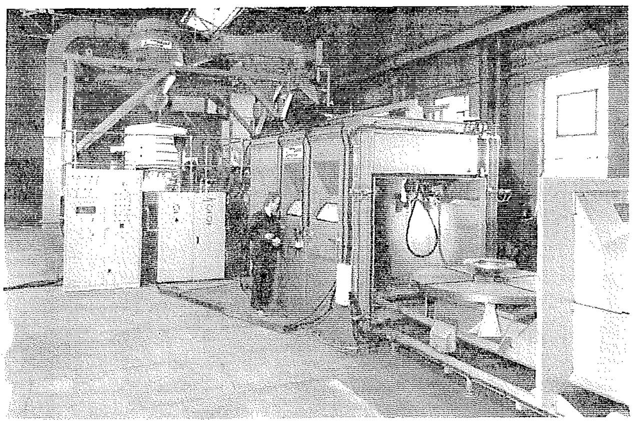

Figure 9 A fan is used to generate the recovery airflow

The flowing examples illustrate how the process has been adapted to peen otherwise inaccessible areas.

EXAMPLE 1. The service manual of the Pratt & Whitney JT8D aero engine demands that the low pressure turbine shaft is removed from the engine after an initial interval of 10,000 cycles. However, when the shaft oil holes have been shot peened the shaft may operate for 20,000 cycles prior to removal. The technique employed utilizes a side firing nozzle which projects the media from inside the shaft outwards through the hole. An externally mounted deflector reciprocates through the hole causing the media to deflect and impact upon the wall of the hole. (Figure 10) Oil holes of 3.5mm diameter have been peened and holes down to 2.5mm diameter can now be processed.

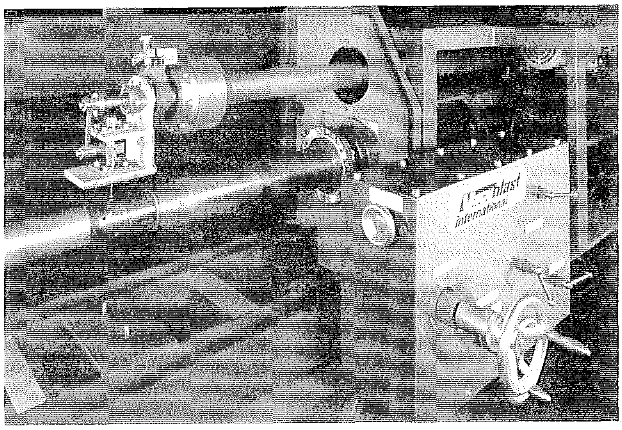

Figure 10 Oil holes of 3.5mm diameter are peened

EXAMPLE 2. The fan blades of the CFM International CFM56 aero engine are held in the fan disc by dovetail roots which mate with corresponding slots in the disc periphery. The pressure faces of these root slots are shot peened. The machine design makes use of a programmable control system to pass a deflector slot peening tool through each dovetail root slot to process the pressure faces. Each peening pass is followed by an index of the required increment until all the slots have been processed. (Figure 11)

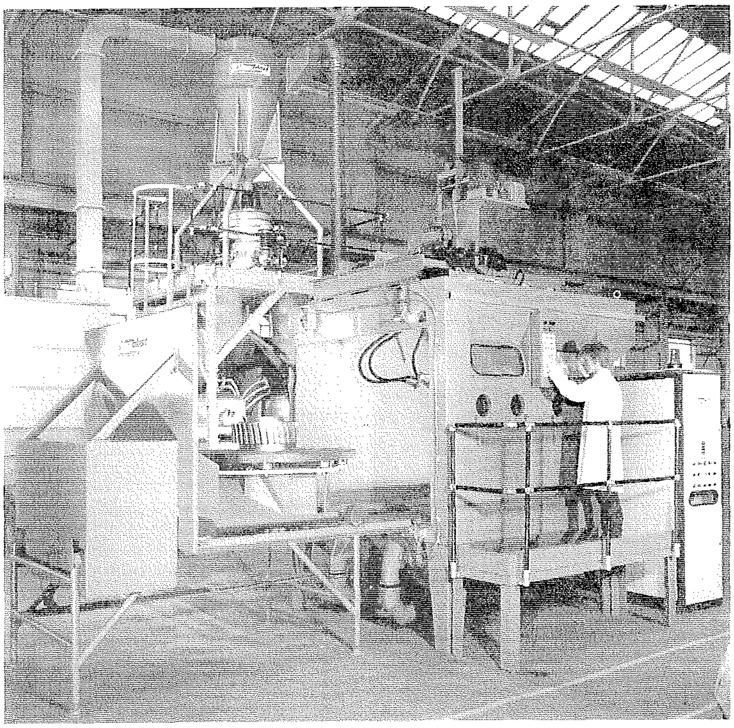

Figure 11 CFM fan blade root slots are shot peened

EXAMPLE 3. The fir-tree roots of the fan blades of the Rolls-Royce RB211 aero engine are shot peened. Batches of four blades are peened sequentially in a machine also equipped to peen fan disc slots. (Figure 12)

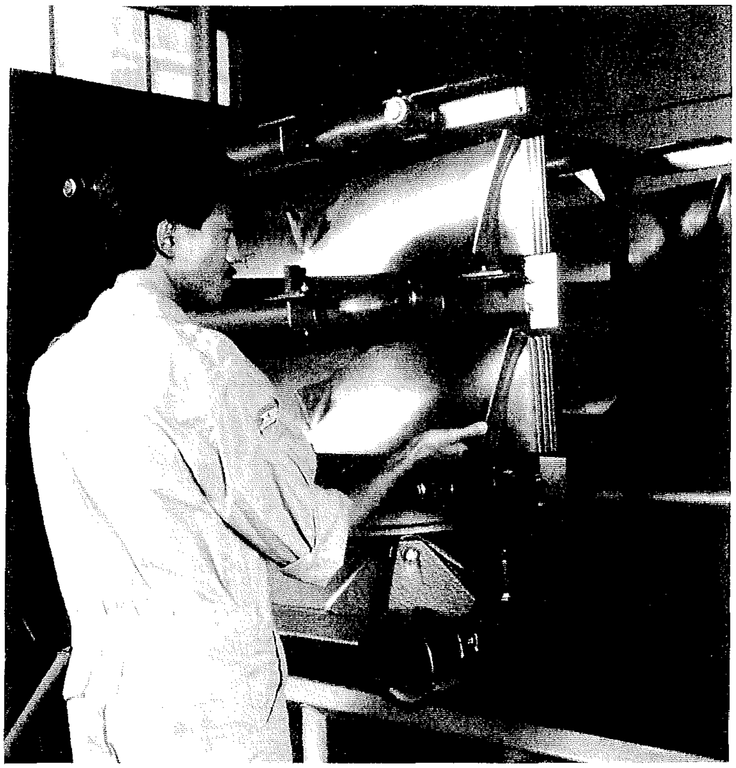

Figure 12 Rolls-Royce fan discs are peened

EXAMPLE 4. The internal clevis areas of the engine pylon pick-up bracket for the A320 Airbus are processed using a rotating side firing lance which is manipulated to track across the slot area. This manipulator can also shot peen holes of diameter 5mm or more. (Figure 13)

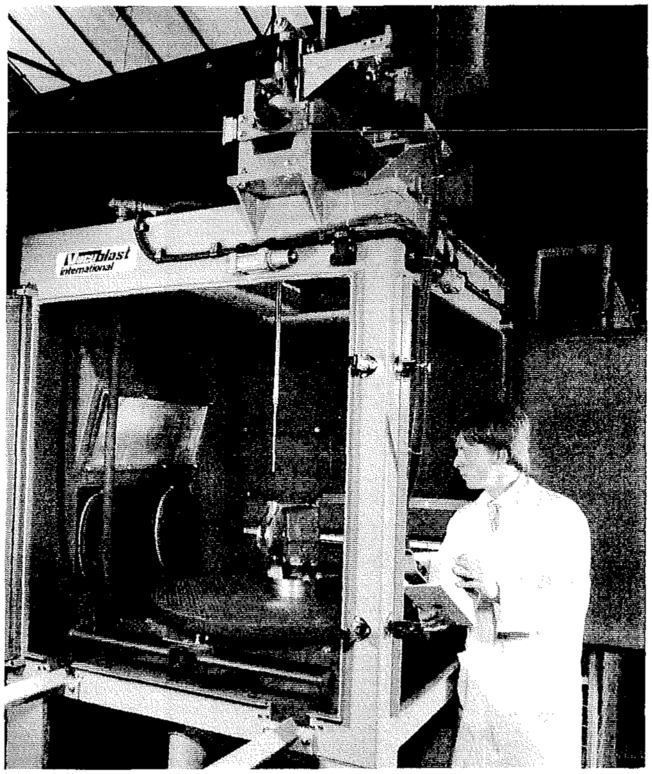

Figure 13 Processing engine pylon pick-up brackets

EXAMPLE 5. The internal bores of landing gear benefit from shot peening both during manufacture and in rework. In this facility a rotary head propels media whilst rotating at high speed. A computer controller monitors the speed of rotation and linear progression of the head to ensure uniform coverage. (Figure 14)

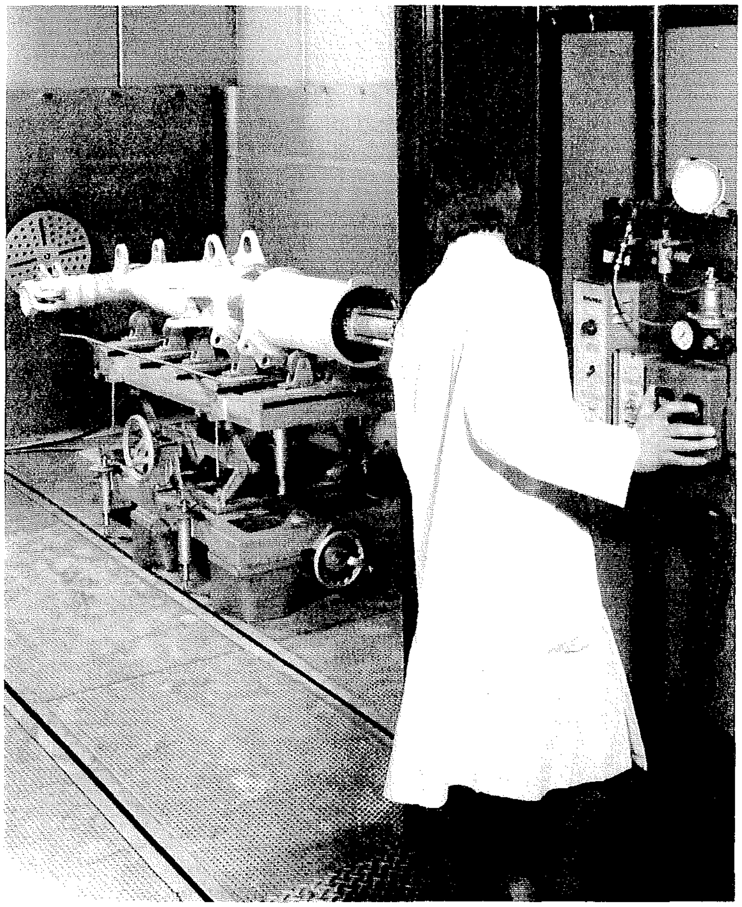

Figure 14 The internal bores of landing gear benefit from shot peening

In conclusion, it can be seen that today's growing pressure for quality and supplier accountability is placing exacting demands affecting all shot peening equipment suppliers and users. The technique has suffered badly from an outdated image and its associated relationship with sand blasting. This problem with its depressing effect on investment management time, came to a head in Europe in the late 1970s when a major review of the process was undertaken. The outcome of this period of change proved to be significant in beginning a revolution in the way shot peening was viewed.

The results of this re-evaluation spread quickly throughout the world's aerospace production and services industries, and produced increasing demands for improvements in process predictability and reliability. These changes echoed exactly the growing importance that the evolution of lighter, more fuel efficient aircraft designs were placing on the old production technologies.

As aircraft designers look to the flying machines which will service the 21st Century travellers' needs, the challenge to the shot peening industry is clear. The next 10 years will place huge emphasis on the process and its development and it is in the close co-operation of the aerospace and shot peening industries that this challenge will be met.

Stephen Williams *is Engineering Manager of Vacu-Blast Limited, Slough, U.K., a company which has been involved in aerospace surface treatment and finishing for 50 years. Mr. Williams gained an honors degree in materials technology from Coventry Polytechnic and joined Vacu-Blast in 1985 as a Graduate Development Engineer. He is now responsible for the company's engineering design and development operations.*