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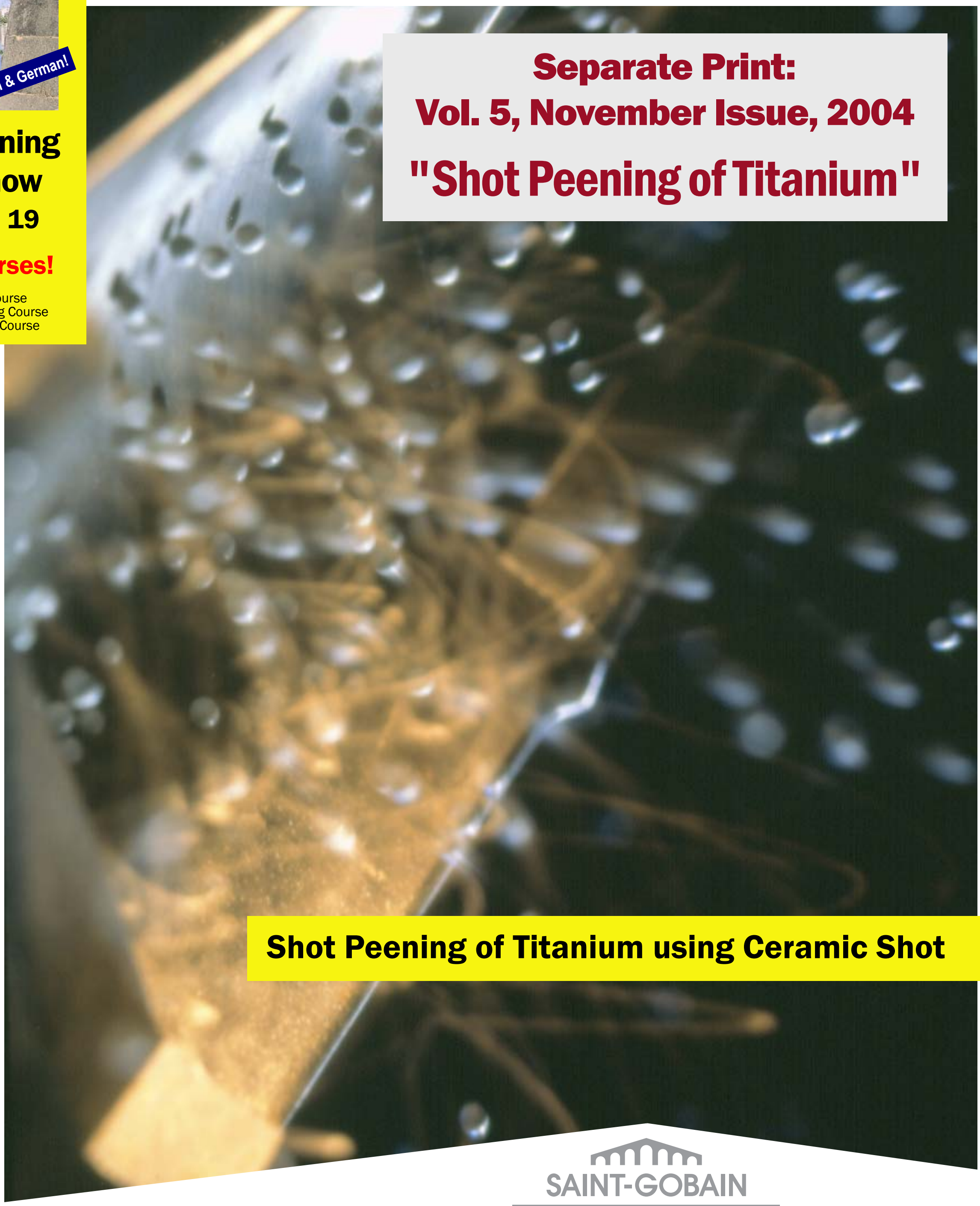


Separate Print:
Vol. 5, November Issue, 2004

"Shot Peening of Titanium"

Shot Peening of Titanium using Ceramic Shot

SAINT-GOBAIN
ZIRPRO

Shot Peening of Titanium

A typical application with ceramic shot. Latest results and perspectives.

Zirshot, Ceramic Media dedicated to High Performance Peening

Round shape, smooth surface, high elasticity, hardness and toughness and narrow size range. Each of these is constant during use. Zirshot generates no dust and is efficient at very low energy levels. Zirshot is included in the main aerospace standards and specifications.

Main characteristics
Crystallographic analysis: Zirconia 68 %, Vitreous phase 32 %, No free silica, Chemically inert
Physical properties: Density: 3.85, Bulk density: 2.3 kg/l Young's Modulus: 330 GPa, Micro hardness: 700 HV1

First Steps: Wet Processes in the early Eighties

The initial purpose was to enhance performance and reliability of already established wet shot peening processes. At that time, due to the aggressive dust generated by fast breakage, glass beads were mainly used in wet peening processes, in order to avoid any abrasion or embedment in items and to smoothen the surface.

The main advantages of ceramic shot over glass beads in the wet process can be described as follows:

1 . Zirshot does achieve better results with no dust emission and far lower breakage rate, resulting in the very long life time of the working mix in the machine. In practise, the replacement of Zirshot is mainly due to cleanliness requirements for the working mix rather than the wear or breakage rate of the shot.

2. The higher density of Zirshot versus glass beads, offers three benefits in operation:
-Faster coverage: 50% higher mass concentration of Zirshot in water for the same bulk concentration providing higher efficiency of the peening stream.
-Compressed air and energy saving: lower air pressure for the same Almen intensity and bead size (fig. 1).
-Reduced water consumption: the faster decantation allows washing of the parts immediately after peening with the clear water taken at the surface of the blasting mix (closed circuit).

3. Reduced machine wear: due to its greater smoothness, Zirshot preserves the machine, especially the gun feeding and working mix recycling pumps.

4. Facilitated process control: attributable to its toughness, Zirshot does not generate dust. No shot wearing or bursting, with the results being consistent.

These attributes made a success of Zirshot in wet processes for engine manufacturers and their blade suppliers, airline repair and maintenance shops, shot peening and subcontracting companies…

Latest Developments

During the last couple of years, the focus on economic aspects has reinforced the need for higher industrial performance and process simplification. This is still pushing towards the testing of ceramic shot in dry processes.

The purpose is to switch from the wet to the dry process, substituting steel shot as well as glass beads, keeping the advantage of no polishing and no decontamination operations.
This possibility had been demonstrated through a study presented at ICSP'3, International Conference on Shot Peening in 1987 (fig. 4).

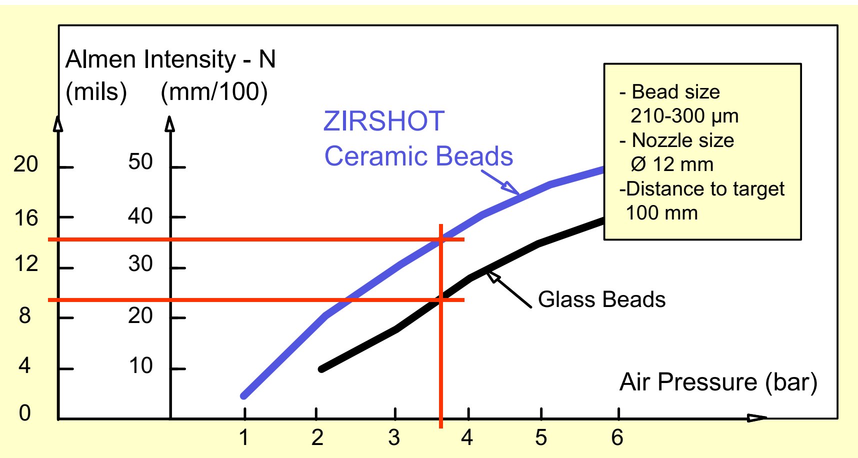


Fig. 1: Due to its higher density, when used in a wet process, Zirshot provides higher mass flow and Almen intensity for the same air pressure (Saint-Gobain ZirPro, ICSP'4, 1990).

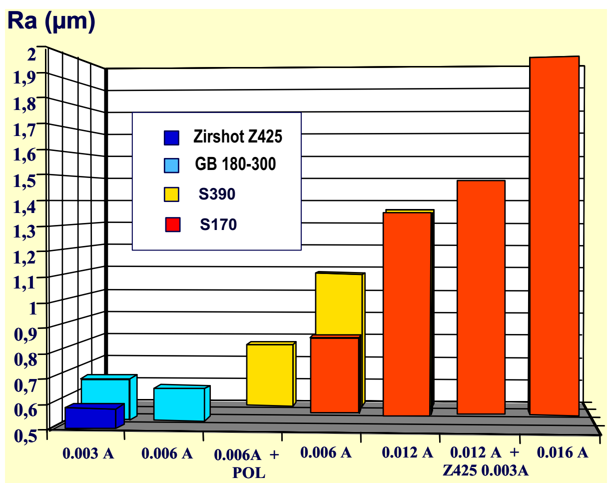


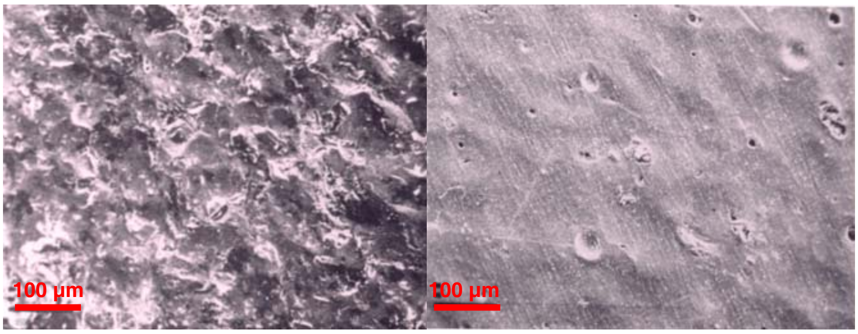
Fig 2: H.E. Franz, A. Olbricht, ICSP'3, 1987: Roughness of titanium after dry peening with several shot types.

Lately, a world leader in blade technology validated Zirshot in the dry process.

In dry process, compared with glass beads and steel shot, Zirshot produces enhanced fatigue performance, both for life time and fatigue strength of Titanium alloys. Most of the explanation lies in the very smooth surface after peening with Zirshot (fig. 2 & pict. 1), combined with the high level of residual compressive stress at the surface which avoids or delays crack propagation initiation.

Consequently, it becomes possible to shot peen the face and the root of a blade with the same equipment and in the same operation.

Remarks:
1. It is also possible to reach low levels of roughness with other shot types, but glass beads need to be replaced by new ones after short periods of use and steel shot requires finishing operations after peening. Both require decontamination after peening.
2. With Zirshot, fatigue life time improvement (fig.3) is growing by reducing Almen intensity. This is saving energy, shot consumption and machine wear.
3. In opposition, with steel shot, fatigue life time improvement is growing with Almen intensity (fig. 3). This is due to surface roughness improvement by post polishing operations.
4. Under very low Almen intensities, damage risk to the work part is minimized.



Pict. 1: SEM pictures of Titanium sample surface after peening with glass beads (left) and Zirshot (right). Magnif. 150 x

Validation Tests

To meet the requirement of potential Zirshot users in dry processes, SAINT-GOBAIN ZIRPRO carried out tests at its testing facility in France.

To facilitate the process validation, as fatigue results were already positive, most of the customers required only to meet the main peening specifications (fig. 5), i.e.:
1. The required Almen intensities, even if they are higher than the optimal ones, gave the best fatigue results.
2. The surface roughness which must be kept below the maximum allowed value without post polishing.
3. Residual stress profiles.
Meeting these requirements, fatigue tests can be achieved, but they are not absolutely necessary.

Test Sample Criteria

- Material TA6V
- Flat shape, thick enough to allow residual stress measurement.
- One slice has been edged in order to check the preservation of sharp edges of blades under direct peening stream.

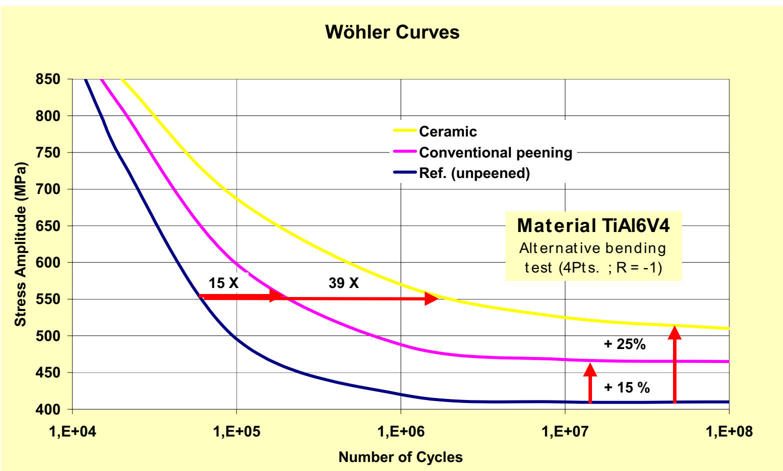


Fig 4: H.E. Franz, A. Olbricht, ICSP'3, 1987: significant improvement of both life time (40 x) and fatigue strength (+25%).

Test Procedure

Several peening parameters were applied with Zirshot in a dry process. Then the samples surface roughness, residual stress analysis and SEM pictures were made.

Results

As shown in fig 5, surface roughness is increasing with Almen intensity. For a larger size of Zirshot (here Z425), there is almost no change of initial roughness up to 0.11 mm A (0.004"-A) Almen intensity. So, when the roughness requirement is less than 0.8 µm Ra, then Zirshot Z425 (425 – 600 µm) is appropriate to maintain the minimum required Almen intensity: at least 0.15 mm A (0.006"-A).
These results have been achieved with the following parameters:

Process	Dry, with direct pressure nozzle
Nozzle size	8 mm (5/16")
Air pressure	0.6 bar (8.7 psi)
Coverage rate	125 %
Impingement	straight (90°/surface)
Target/nozzle distance	340 mm

Residual stress distribution with Zirshot is meeting the most stringent specifications:
- High level of compressive stress at the surface (600 to 700 MPa) can be achieved
- Depth of zero stress can reach 200 µm with Zirshot Z425, with a reasonable roughness of 1.8 µm Ra.

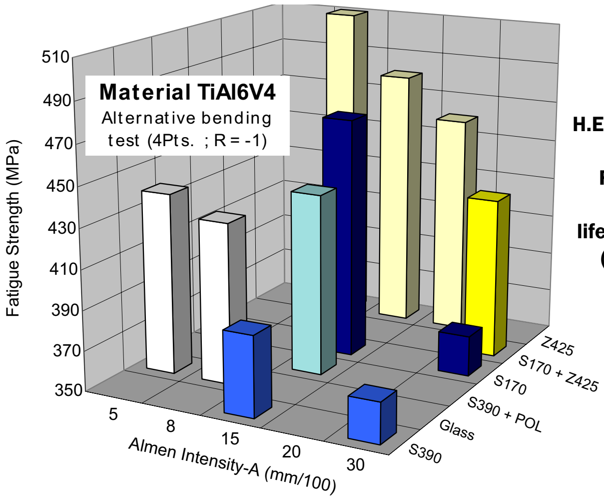
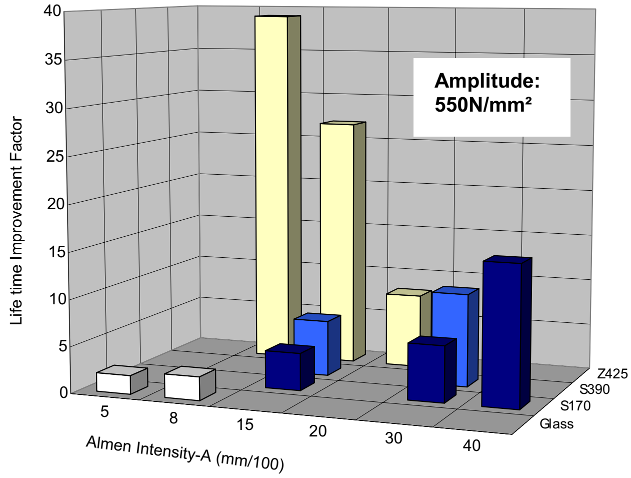


Fig 3:
H.E. Franz, A. Olbricht, ICSP'3, 1987: Fatigue strength (upside) and lifetime improvement (downside) after dry peening with several shot types.



Outlook

Because of the cost saving motivation, the main results of the study presented at ICSP'3 and the tests carried out by SAINT-GOBAIN ZIRPRO allowed clients to change from wet to dry peening process. This led to a lot of progress after validation and qualification for the main engine manufacturers.
As the target was the guarantee of fatigue performance and the savings on fatigue tests and specification changes, the main results of this study were not yet translated into the improvement of technical performance on true parts.

The question would be "why just stop here?" Today, the concern is weight reduction of the aircraft. Ceramic shot has proven to be a technical and cost effective solution for fatigue strength improvement by shot peening. The next step is drawing on the full advantage of Zirshot and significantly increasing component performance.
As this requires expensive fatigue tests on true parts and also changes in specification, the opportunity is then to take advantage of new process validation or new part design.

In addition, as improved results have been achieved on Aluminium alloys and high strength steels, ceramic shot may be considered as a versatile media, able to work on several types of metallic components and compatible with any peening equipment type: compressed air, Venturi or direct pressure system, wet or dry process.
This is an actual opportunity for aircraft engines which are made of different alloys (Titanium, Nickel base, Aluminium, stainless and high strength steel…).

SAINT-GOBAIN ZIRPRO`S intention is now to work with potential users in three directions for testing using Zirshot:

1. For Titanium, the possibility is now opened to spread the use of Zirshot on the complete blade including root, face and foil, and also for disk, and "blisk" applications.
2. The shot peening of the main engine shaft.
3. The shot peening of the different types of landing gear made of high strength steel, Aluminium or Titanium alloy.

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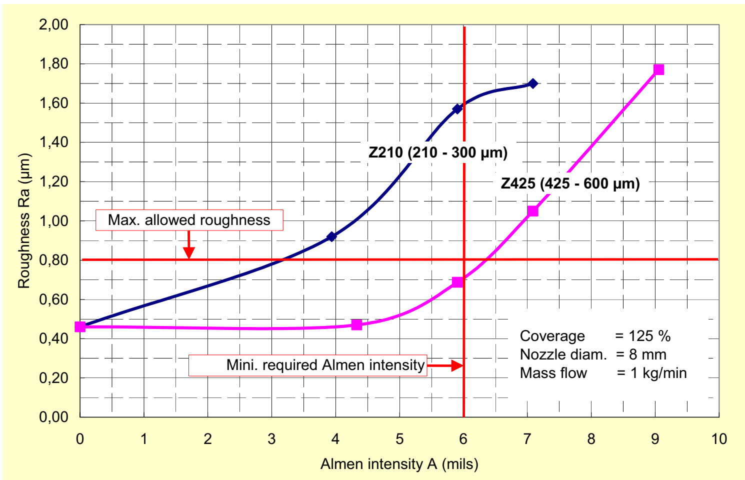

Fig. 5: Optimisation of Zirshot size according to minimum required Almen intensity and maximum acceptable roughness. Zirshot Z425 is appropriated (Saint-Gobain ZirPro 2001).