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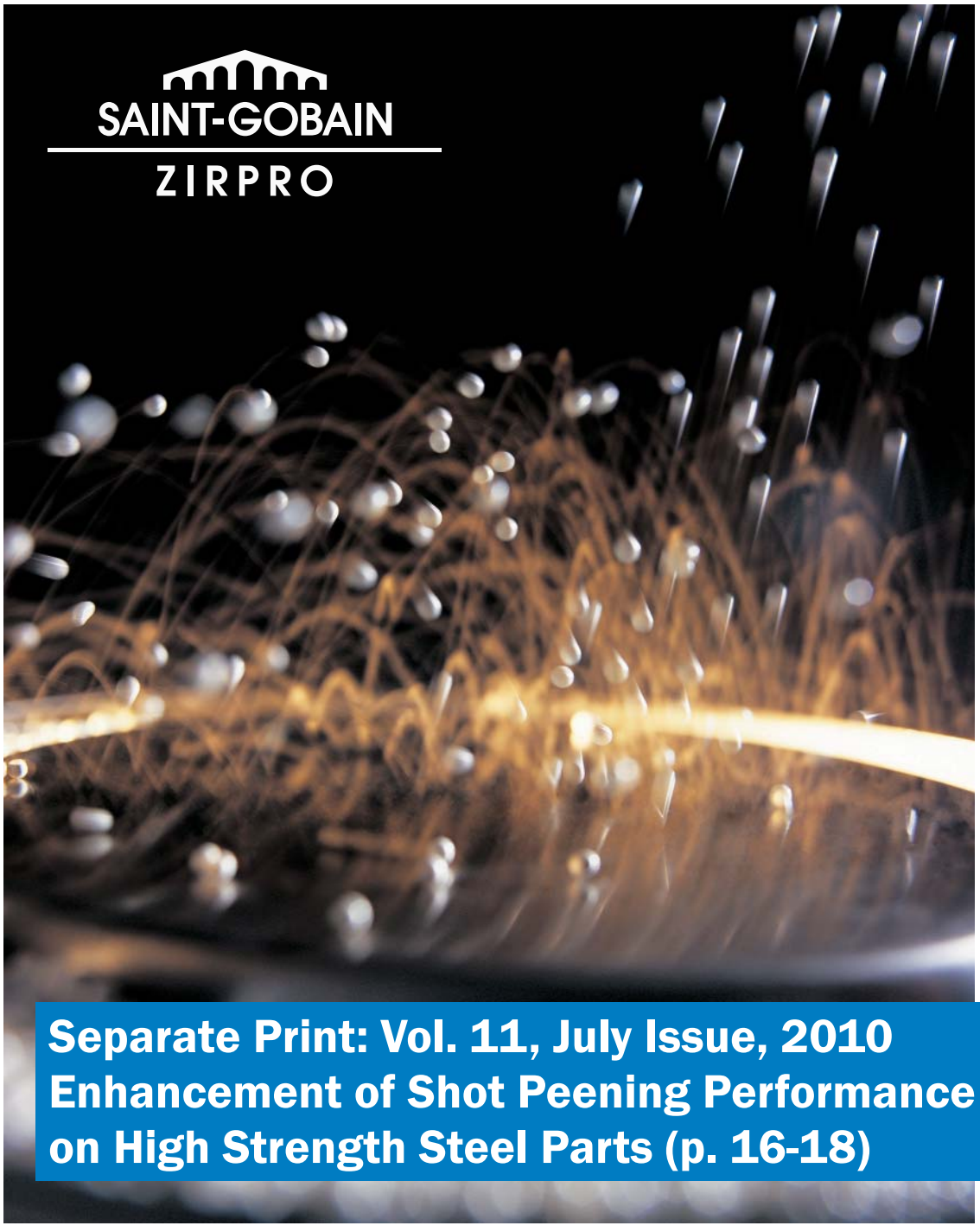

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Enhancement of Shot Peening Performance on High Strength Steel Parts (p. 16-18)

Enhancement of Shot Peening Performance on High Strength Steel Parts

Weight reduction is a critical requirement in the transportation industries. 10% mass off a land vehicle powered with a combustion engine can generate 5% fuel consumption saving [1]. In this purpose, the use of high strength steel combined with proper part and process design is one of the credible solutions.

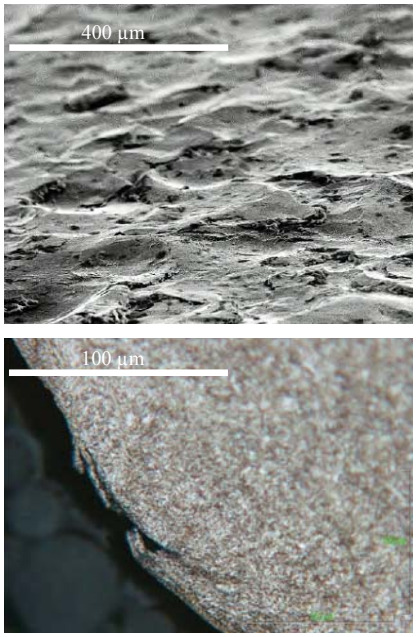
High strength steel (HSS) dilemma

HSS could simply be defined as steel having a high tensile strength, in the range of 400 to 1,200 MPa and above. This induces two main consequences: high mechanical properties and notch sensitivity. Taking this into account during the sizing steps of the mechanical part design gives on the one hand a high potential for weight reduction by integration of the high HSS mechanical properties, and limitations on the other hand from the difficulty to manage HSS lifetime and fatigue strength after some damages have been induced throughout industrial processing steps.
Note: HSS are available in a wide range of alloy contents. Manufacturing and heat treatments processes may change significantly the fatigue behaviour of the same original material.

High strength steel peening benefits and limitations

Shot peening is recognized as an industrial process providing enhanced material behaviour in cyclic loading applications. At the beginning, in most of the cases, the shot peening benefit was used as additional design safety, allowing mainly tightening of the scattering of fatigue results. Shot peening has also been used as an ultimate solution to increase the lifetime of mechanical components after the design phase was closed. Due to the requirements of automotive and aircraft industries, some recent developments have led to effective and significant weight reduction using highly sophisticated shot peening operations such as multi peening steps, shot peening combined with surface conditioning, and many other expensive solutions. This requires increasing the shot peening performance up to the point when lifetime, or even fatigue strength are significantly enhanced and actually predictable. Thus, shot peening benefit can be integrated into the early steps of design. HSS being heavy material is definitely the one material for which performance enhancement has been the highest and the quickest to be translated into actual weight reduction projects.

History of some improvements in high strength steel peening



Picture 1: SEM picture of the surface condition after single step peening with steel shot (top) and micrograph cut of typical defect induced by steel shot peening (bottom)

Single step peening with coarse steel shot

In the frame of weight reduction strategy, the basic idea in order to improve fatigue performance of HSS after shot peening is to balance deep high tensile load with deep compressive residual stress. This is why, in a first approach, heavy shot peening treatments with coarse steel shot under high Almen intensity were successfully applied.
Nevertheless, mass removal results in less material to accept load and higher level of local stress with a maximum very often located close to the component surface.
Provided that HSS is notch sensitive and despite the real gain in fatigue lifetime, the surface defects induced by such intensive peening were severely reducing the possibility to remove mass with HSS (see picture 1).

Dual step peening with steel shot

The idea was then to operate a second peening with finer steel shot at low Almen intensity, providing some kind of surface repair and conditioning.
This worked very well, bringing significant and reliable lifetime improvement that offered real possibilities to remove mass from the parts. The cost of this

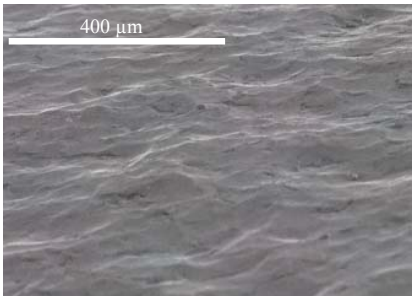
dual peening (almost double cost) was a heavy constraint and it was only applied to precision springs in batch tumbling machines or top range vehicles, mainly for performance reasons without using the weight reduction capability which would require changing the design itself.

Single step peening with very fine Zirshot®

When the surface is very hard, around 1,000 HV, for Nitrided precision springs or carburized transmission gears for instance, single peening with very fine ceramic shot under low Almen intensity and high coverage rate are now recognized and industrially used to get significant high fatigue life improvements and very low operating cost for peening [2][3][4].

Dual step peening with Zirshot®

The ultimate development was made by optimizing the first peening step with steel shot, thus minimizing detrimental effects at the surface (see picture 2)

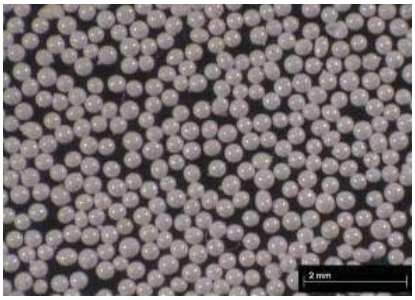


Picture 2: SEM picture of the surface condition after 2nd step peening with Zirshot® The surface has been smoothened; no more visible surface defect

while keeping the same depth of compressive layer and using fine ceramic shot for the second peening step.
This solution significantly reduced the operating cost of each peening step, brought outstanding surface condition, very high level of compressive stress at the surface and also the genuine advantage of reducing the damage ratio, which was not possible with steel shot (see chart 5).
This solution requires using two different types of peening equipment in the same production line. Therefore, whatever is the pre-established process, single or dual step peening, one out of two machines already in use with steel shot should be converted to ceramic shot, or new equipment should be installed which gives the opportunity to finely customize them for ceramic shot use.
Application example:
This dual step peening process, first with steel shot followed by ceramic shot provides a significant increase in fatigue lifetime of automotive suspension coil springs. This outright improvement has been used industrially for several years to integrate shot peening benefits into the early steps of suspension systems design. This clearly supports the automotive OEM need for weight and cost reduction [5].

Zirshot®-Y, new generation of ceramic shot for intensive peening applications

A new type of ceramic material with enhanced characteristics versus original type of ceramic shot has been brought to the market (see picture 4):



Picture 4: Microscope picture of Zirshot®-Y; round shape, smooth surface, tight size distribution

-Specific gravity 4.6, instead of 3.8,
-Hardness HV 1,000, instead of HV 700.
As a direct consequence, it is possible to reach 30% higher Almen intensity for the same impact speed and shot size vs. original version of ceramic shot.
The residual stress profiles are as deep as those obtained with steel shot. Surface condition and level of compressive stress at the surface are as good as when operating a second step peening with the original version of ceramic shot (see chart 3).

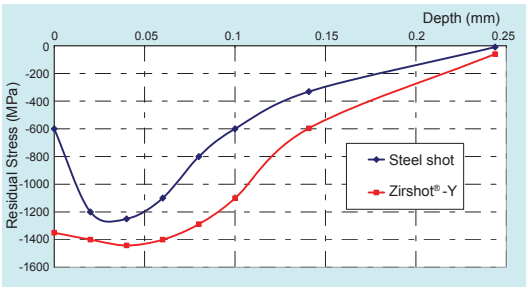


Chart 3: With comparable depth of compressive layer, residual stress profiles show much higher compressive stress at the surface after peening with Zirshot®-Y ceramic shot vs. Steel shot

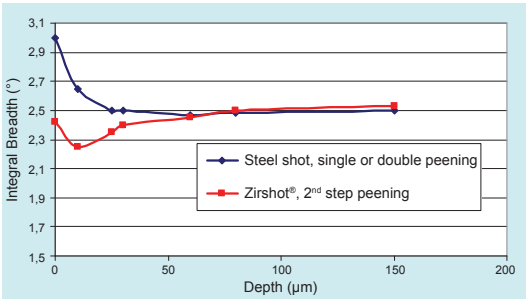


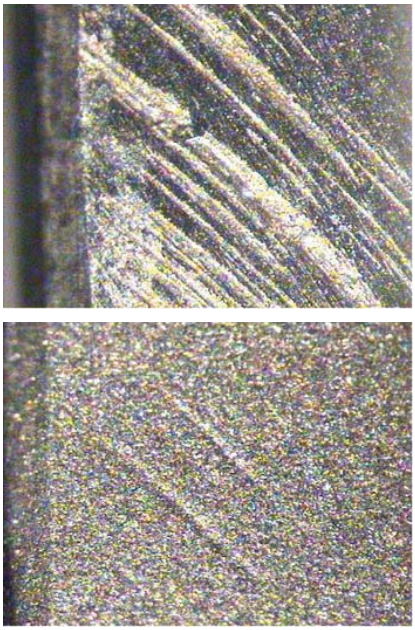
Chart 5: Dislocation density (integral breadth of diffraction pick) is much lower after peening with Zirshot® vs. steel shot

This new ceramic material is also much stronger than the original ceramic shot type, allowing for reduction of the shot consumption for the same Almen intensity or even reaching Almen intensities of the C scale with acceptable shot consumption.
The very gentle behaviour towards the machine and lower need for power as compared with steel shot ensure lower operating costs in turbine peening equipment.
In cases using nozzle equipment, the fatigue performance is significantly enhanced with really low impact speed of the ceramic shot, leading to effective use of very low air pressure, therefore significantly reducing compressed air consumption.

Typical applications and main targets with Zirshot®-Y, new type of ceramic shot:

- Leaf springs
Lightening, elimination of stress peening and associated tooling and handling operations and costs…

- Transmission gears and shafts
Lightening or much higher load within the same design in terms of material and sizing, elimination of post operations such as 2nd peening step or surface conditioning…
Reduces the effect of machining groves (see picture 6).



Picture 6: Microscope pictures of a gear tooth surface showing groves after machining (top) and the same place after peening with Zirshot®-Y where groves have been "repaired" (bottom)

- Suspension springs
Lightening in the frame of design change, avoids the stress peening process, avoids the 2nd peening step.

- Hollow torsion, stabilizer bars and suspension and chassis parts
In these cases, weight reduction comes from the material removal at the core of the mechanical part. This creates a difficult access area for internal shot peening process with nozzle machine. Thanks to its high elasticity, the new type of ceramic shot delivers a high level of energy with much efficiency and consistency, even after several ricochets.

- Others
Diaphragm springs for clutch, landing gears, main shaft of aircraft engines, gears and power transmission elements for helicopter and aircraft engines…

Recommendations for ceramic shot use

- Ceramic shot specific behaviour
Ceramic shot has a very specific behaviour in that it breaks into only a few pieces and shows hardly any effect of wear. As very positive consequences, ceramic shot keeps as new until breaking with its original shape, size, smoothness and hardness, bringing thus, very consistent peening results.

- Energy transfer
Thanks to its high elasticity, ceramic shot is very efficient at very low energy level. This means there is an impact speed limit above which no more energy could be transferred to the target material but would break the ceramic shot. For instance, the new ceramic shot type in the size range 1.0 to 1.2 mm can reach the rather high Almen intensity of 0.17 mm on the C scale for a throwing velocity of only 45 m/s. This induces a very low shot consumption and machine wear. Using a higher shot throwing velocity would only break the shot and bring no higher Almen intensity.

- Machine design
Ceramic shot being almost twice as light as steel shot and generally used in fine size, as for any shot care, and in particular when using wheel turbine equipment, the actual bulk shot flow rate should be taken into account for the sizing of the wheel turbine itself, recovery and recycling systems. This will avoid shot crushing inside the wheel turbine impeller and will insure the capability of the air separator to pick out a few broken shot among a large bulk flow.
For the same reasons, dust collector and air circulation in the machine should be designed in order to keep the fine and light ceramic shot inside the machine: Low air speed in the ducts, drop off box or cyclone in front of the dust collector, and a little sieving device at the waste end the air washer to send back re-usable shot inside the machine.
Ceramic shot being non-magnetic, a specific device should be used to meter the shot flow rate.
The energy yield with ceramic shot can lead to work under very low pressure with nozzle equipments, which may require specific pressure pot design.

Conclusion and perspectives

With regard to specific application cases and discretion about proprietary fatigue results for the users of ceramic shot, it was not possible to disclose fatigue results in this paper. Nevertheless skilled readers will appreciate the information delivered here about the outstanding performance of ceramic shot, especially with the new type in single step peening operation, thus allowing it to reach the target of lightening HSS parts.
Sizing, design, material performance and neighbour steps of the industrial process [3] will also play a major part in the improvement loop.

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