Evolution of the controlled shot peening process in the automotive field

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Introduction

The controlled shot peening process, on a mechanical component, represents the most robust solution to increase its resistance to fatigue; moreover, since it is usually the last operation in the production chain, it does not change the parameters of the previous operations, such as forging, mechanical processing and surface hardening treatments.

The choice of shot peening parameters and minimum values of residual stresses in compression are essential to keep the operation under control; the optimal residual stress, from surface up to deep, profile depends on the type of damage to be solved.

The advantages reached with controlled shot peening are achievable only if the process parameters are strictly predetermined and kept under control, such as:

- Shot speed and range
- Impact angle of the shot flow
- Distance of the piece to be treated
- Exposition time

To be reported on the drawing:

- **Shape, size and hardness of the shot**
- **Coverage**
- **Minimum intensity of shot peening**
- **Residual stresses MPa**

The controlled shot peening process gives high residual stresses in compression, both on the surface and in depth (Fig. 1); however, even using optimal parameters, the surface roughness undergoes a small deterioration (Fig. 2)

The choice of the correct profile depends on the damage mechanism that must be opposed in the images below, the curves for:

- **Bending**
- **Pitting**
- **QT – Micro alloyed**
- **Sheet products**

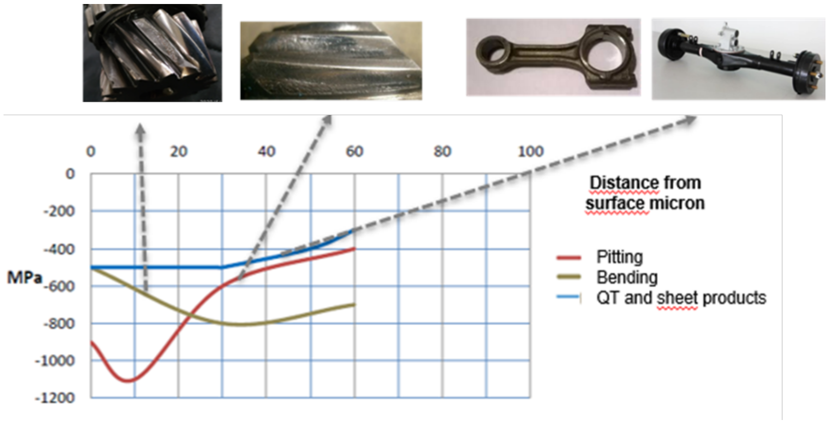

Figure 1 – Residual stress profile in function of the damage mechanism.

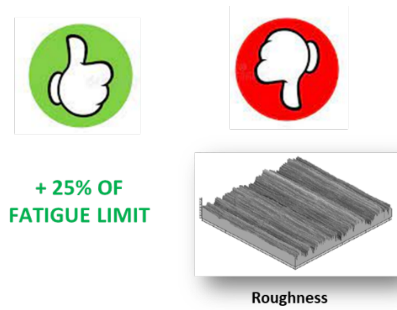

Figure 2 – Worsening of surface roughness after shot peening

The next steps of controlled shot peening, using compressed air equipment, concern the optimization to reduce the surface roughness and further improve the resistance to sub-surface fatigue (pitting).

In this regard, there are some solutions ranging from a final super-finishing to a double shot peening, with a second softer operation in terms of intensity, using both steel and ceramic shot.

The super-finishing process, after shot peening, guarantees a removal of material from the surface of max 15 microns (Fig. 3).

Different details of the gearbox with different geometries were tested, such as gear wheels, secondary and primary shafts and cylindrical crowns (Fig. 4)

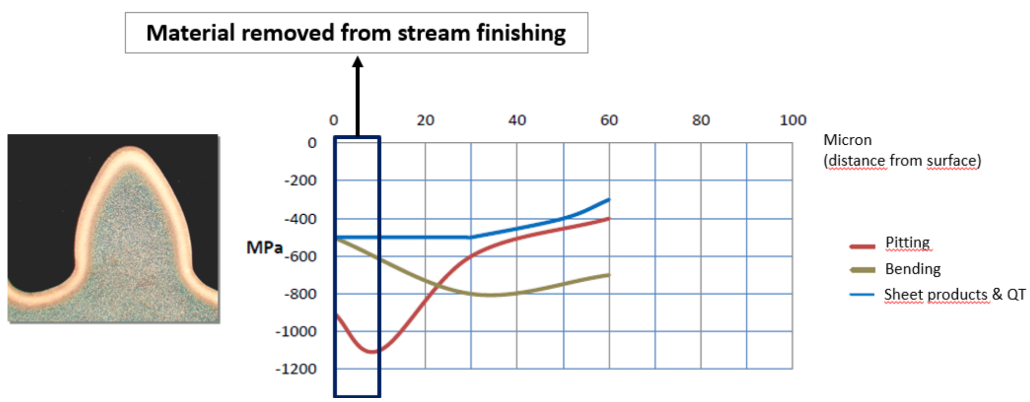

Fig. 3 – Appearance of the depth of material removed during the stream finishing operation.

Pict. 4 – Parts tested with the stream finishing process

The metrological measurements of surface roughness have shown reductions in Ra of about 65% (Fig. 5); this guarantees a considerable increase in resistance to pitting, such as sub-surface fatigue.

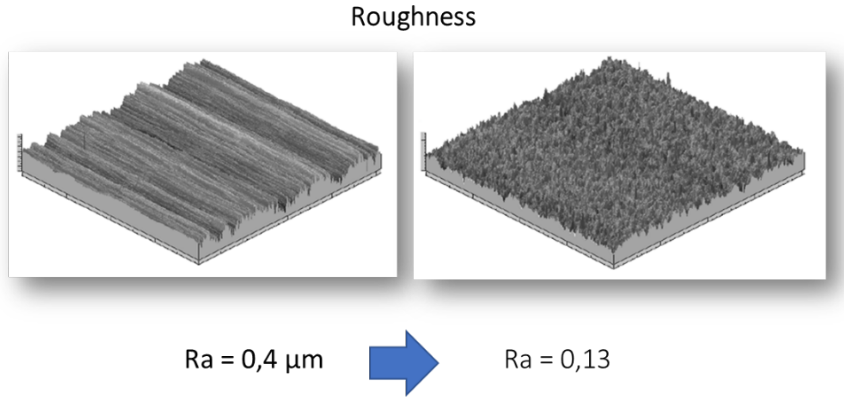

Fig. 5 – Magnification of surfaces, before and after the stream finishing operation.

As for the residual stresses, measured on non-shot peened parts and after the stream finisching operation, it emerged that high values are reached on the surface which are reduced and fade under the surface (Tab. 1). This is very important, since the roughness Ra is very low, as it is possible to evaluate, on some projects, even the possibility of using the superfinishing alone. This obviously depends on the application and the mechanical stresses, due to fatigue, during operation.

Table 1 – Residual stress values measured on all tested components, both on the surface and at a depth of 30 microns.

SAMPLE	RESIDUAL STRESS MPa	
	Surface	At 30 micron
Secondary shaft output	-1082	-412
Driven gear 1^ speed	-892	-461
Driven gear 2^ speed	-1012	-389
Reverse gear	-994	-401
Cilynder crown	-998	-398

Finally, fatigue tests, performed on test samples representative of the application with a shape that has a fitting that simulates the bottom tooth of a gear, have shown that controlled shot blasting guarantees an excellent increase in fatigue resistance (+ 20-25%); since this is an operation performed after the surface hardening process, it allows not to change the parameters that are upstream of the production chain. The subsequent stream finishing further improved the fatigue behavior by about 30% (Fig. 6). The equipment used for the test is a vibrofor with a run-out of 5 million cycles (Fig. 7).

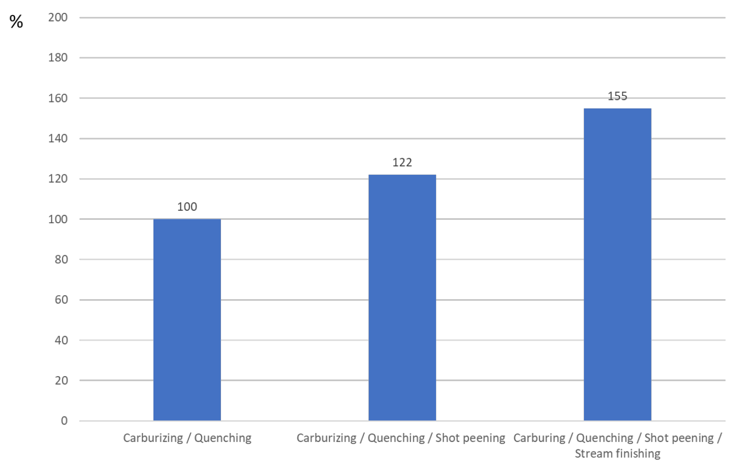

Fig. 6 – Results of fatigue test.

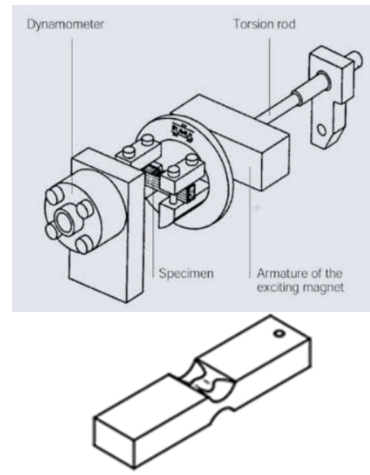

Fig. 7– Craktronic resonant machine and sample

Next steps

The activity will go ahead and includes:

- ***Double shot peening (*) - Steel + Steel***
- ***Double shot peening (*) - Steel + Ceramic***

- ✓ Preparation of 60 fatigue samples - 30 April 2022
- ✓ Vacuum carburizing – Quenching in gas - May 31, 2022
- ✓ Double shot peening process - 30 June 2022
- o Fatigue test with 5 mil cycle run-out - 30 September 2022
- o Evaluation of the results - 15 October 2022

(*) The second shot peening involves a reduction of the Almen intensity in order to significantly reduce the surface roughness.

Conclusions

- **CONTROLLED SHOT PEENING**

Guarantees an increase in fatigue performance of about 25%; since this is the last operation, the previous parameters of the supply chain are not changed (mechanical processing / hardening treatments).

- **STREAM FINISHING POST SHOT PEENING**

It combines the low surface roughness with the residual compressive stresses of the shot peening, improving both the resistance to both pitting and bending.
Comparative fatigue tests on test samples representative of the application have shown increases in fatigue resistance that can reach up to 70%.

- **DOUBLE SHOT PEENING**

It represents an alternative to stream-finishing, where the first shot peening determines residual tensions in depth and the second, with a lower intensity, refines the surface with a reduction in roughness.