

STRESSONIC SHOT PEENING (Ultrasonic Process)

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SONTAS – Nantes - France

1 – Presentation of SONATS

SONATS is an engineering company with industrial applications in the field of characterisation and behaviour of the materials. Its main activities are :

- Taking into consideration the residual stresses during the part's conception as well as the maintenance. Specialised engineers measure the residual stresses thanks to portable equipment based on the X-ray diffraction process.
- STRESSONIC® shot peening : development, conception and manufacturing of automatic industrial machines, shot peening subcontracting in SONATS' workshop or in situ.

Our strategy is to offer a full set of services: definition of the customer's need concerning the part's lifetime, implementation of an industrial innovative surface treatment to increase the lifetime of this part and finally validation of the effects of the treatment thanks to the analysis of the residual stresses.

2 – Classic Shot Peening

Shot peening is a well-known mechanical surface treatment which allows to increase part's resistance to fatigue and to corrosion by introducing compressive residual stresses.

A considerable amount of literature has been published on the subject allowing to have a good knowledge on the subject.

3 – The STRESSONIC® Shot Peening : Historic

SONATS has been developing the STRESSONIC® Shot peening (ultrasonic shot peening) in Europe since 1996. The industrial interest of this technology has been proved : gains in terms of resistance to fatigue, but also production and industrialisation gains.

Industrial applications have been made in the field of aeronautic, nuclear, shipbuilding, electromechanical, offshore and heavy industry. A further presentation of some applications will be done.

SONATS is also developing other applications in the field of high technology and traditional mechanic with automatic and compact machines or portable equipment called NOMAD allowing easy maintenance or shot peening of new parts in situ without dismantling or parts which cannot be reach easily.

The STRESSONIC® shot peening can also be used to straighten metallic panels : peen forming. We will talk about it during this presentation but some applications will be industrialised within the end of 1999 in the shipbuilding and the aeronautic industry.

4 – The STRESSONIC® Process

4.1 Process description

A piezoelectric transducer emits ultrasonic waves at 20 kHz. The waves are amplified when they travel through an acoustic booster, in a housing which contains the parts to be treated and the shots (generally the balls of ball bearings). The dimensions of the vibrating parts allow vibration amplitudes of 50 to 200 µm to be attained.

The shots strike the vibrating walls and are reflected off the surface. Then, they collide with one another. The balls are scattered randomly throughout their encasing, like molecules of gas. An homogeneous treatment is then obtained on the surface of the casing.

The parts being treated do not come into contact with the wall and the ultrasonic waves do not travel through these parts.

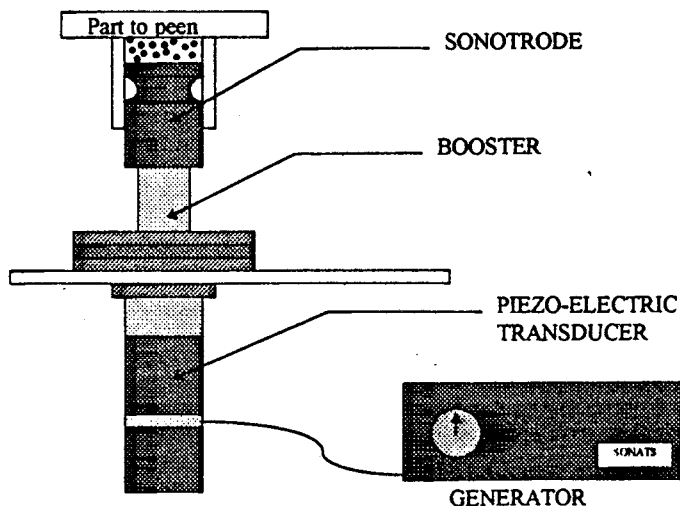


Figure 1

4.2 Constituent elements of a STRESSONIC® Shot Peening Equipment

* Generator :

- Frequency of the generated signal : 20 kHz (possibility to work with 30 or 40 kHz.).
- Consumed power : 1000W with a variation of amplitude thanks to Rhéovar.

* Emitter :

The emitter supplied by the generator is a transducer. The ceramic part allows to transform the electric energy into mechanical energy oriented according to the nature of the neighbouring materials.

* Booster :

The booster allows to fix the type of sonotrode necessary to complete de shot peening treatment. The booster transmits the amplified mechanical vibration to the sonotrode.

* Sonotrode :

The main role of the sonotrode is to ensure a uniform amplitude of vibration at each point of the surface in contact with the shots. The target is to get an homogeneous shot peening treatment on the part. The shape of the sonotrode determines the maximal amplitude (power) of vibration. The emitter, the booster and the sonotrode are sized to get a frequency of 20 kHz.

* Housing

The housing allows to contain the shots during the shot peening treatment. The shots are confined in a space delimited by the housing, the sonotrode and the part. This housing can have every kind of requested shape to be adapted to parts with a complex geometry. It is possible to manufacture housings with changeable geometry in order to use a single system for a family of geometry.

* Shots

- The low quantity of balls used for the STRESSONIC® shot peening enable to work with high-grade shots. Therefore the surface state is different from that obtained with classic shot peening. The roughness is lower which is good to improve the part's behaviour in service. Every kind of shots can be used (steel, stainless steel, ceramic, ...).
- The choice of high-grade projectiles allows to :
 - eliminate every risk of breakage during the treatment
 - suppress the defects on the surface of the parts
 - reduce the consumption of shots
 - ensure a good repeatability of the treatment
- It becomes easier to link together treatments with shots of different diameters because the substitution of the shots is very fast (< 5 minutes).

4.3 Significant parameters and associated controls.

*** Type of balls : diameter, nature et hardness**

- diameter : la kinetic of the balls within the STRESSONIC® shot peening housing is independent of the diameter of the balls. The diameter of the balls allows to choose the kinetic energy of the impact.

- nature and hardness : the choice of high-grade projectiles ensures that there will be no damage of projectiles. This is economically possible because the quantity of shots that is used is very low (about a few tens of grams).

*** Quantity of balls in motion**

- we can show that there is an optimal mass of balls to put in the housing
- we also note that a difference of the mass amounting 10 to 20 % in comparison with the optimal mass modifies only a little the kinetic of the balls.

*** Vibration amplitude of the sonotrodes**

- the amplitude of vibration depends on the amplitude of the electric signal sent to the emitter and to the frequency of the acoustic booster. The amplitudes of vibrations of the equipment are controlled in real time allowing to ensure the good running of the process.

4.4 Repeatability

This is worth noting that one of the main advantages of the system is that there is no loss of balls. The balls are confined in a housing delimited by the part, the fairing defining the balls' traffic and the surface of the part that has to be treated. In this way, the system allows to ensure a good repeatability of the treatment because it is always the same mass of balls with the same parameters that is in contact with the part that has to be shot peened. A quality control of the shots is not necessary any more. The self-regulated generators associated to the amplitude controller guarantee a stable and repeatable vibration of the sonotrodes. All the parameters are self-regulated and controlled in real time.

4.5 Validation of a part

The use of projectiles which are different from that recommended in the existing specifications makes it necessary to redefine the specifications.

In order to validate a part the work steps are the following :

- Definition of the shot peening conditions on strips representing the material.
- Conception of both sonotrode and housing.
- Tests of production instructions on sample parts and validation of one instruction : control of the uniformity of the treatment (coverage, residual stress, surface conditions) and local control of the treatment (residual stress profile, Almen control if necessary).
- Repeatability
- Industrialisation with control of the parameters and the associated quality assurance.

5 – Quality and control of the process conditions.

5.1 Follow-up of the STRESSONIC® Shot Peening parameters during the treatment.

The parameters are determined before the treatment and don't change in the course of the operation. The power generator has an automatic frequency corrector allowing to ensure a stable amplitude of motion during the treatment.

There is a sensor in order to control in real time the amplitude. This sensor is connected with an automaton which can start the safety system in case of drift or incident.

5.2 Control of the quality of the treated parts

In order to control the industrial quality of the treatment, the Almen strips are often used. Almen strips are also used for the STRESSONIC® shot peening but they are redundant with the amplitude control which is done during the whole treatment.

The Almen strips are useful to set a STRESSONIC® with regard to a classic shot peening equipment and to control the treatment repeatability.

As for the classic shot peening, in order to be sure of the effect introduced by the shot peening process, we have to control the following parameters :

- residual stresses (surface and if possible undercoat)
- roughness
- hardness
- coverage rate

SONATS has all the necessary equipment, especially portable X-ray diffraction equipment, and works in production line to optimise the shot peening conditions on sample parts by controlling these parameters.

5.3 Recording of the parameters

The parameters are recorded via a connection RS232.

6 - Results

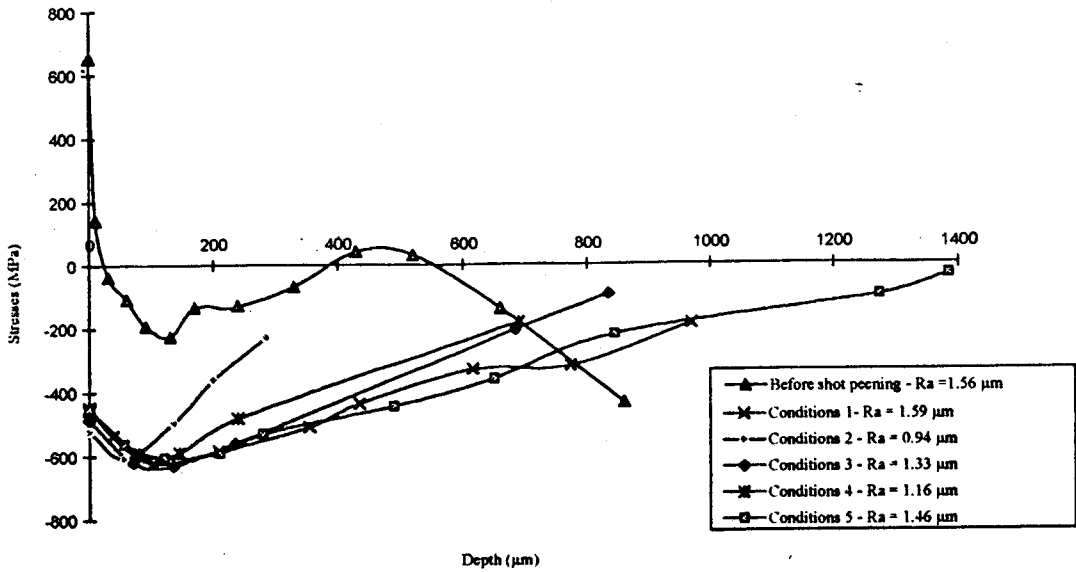
Numerous tests made by SONATS show that the STRESSONIC® Shot Peening generates a lower roughness with the same stresses in comparison with classic shot peening.

The following diagrams show residual stresses and surface profiles obtained on different materials.

► **We note** : with an equal roughness, the surface morphology is very different compared with the classic process. The peaks introduced by the ultrasonic shot peening are less sharp-pointed than with classic shot peening.

Stress profiles for different ultrasonic shot peening conditions

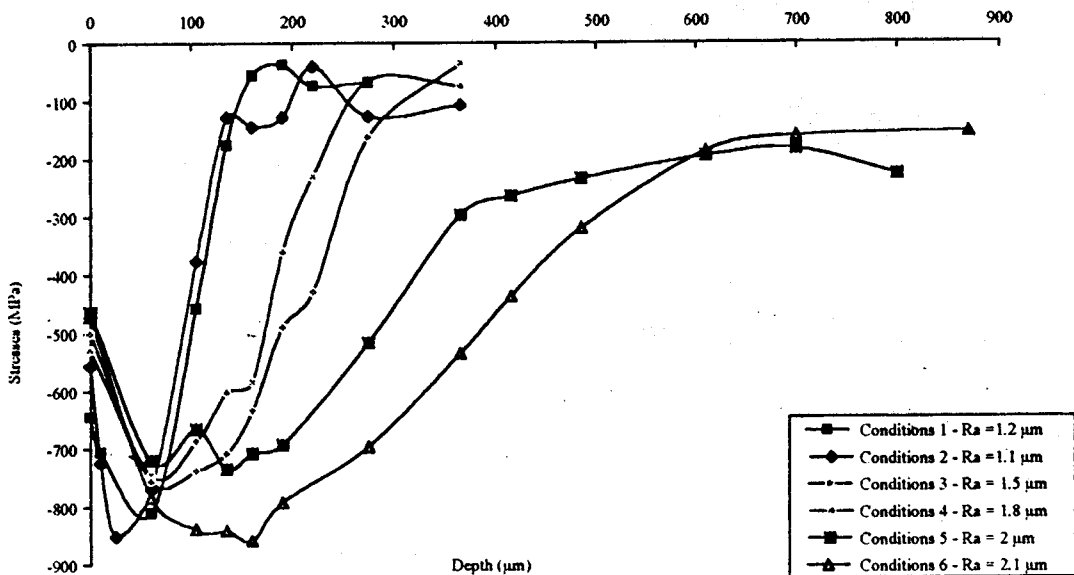
Material : STAINLESS STEEL



Evolution of hardness from 299 to 362 Hv

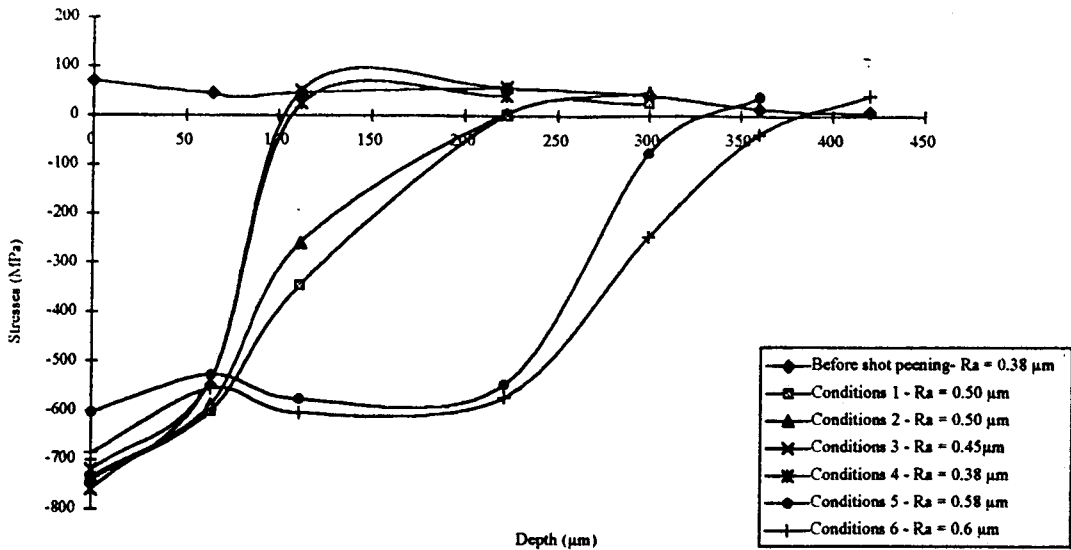
Stress profiles for different ultrasonic shot peening conditions

Material : TA6V



Stress profiles for different Ultrasonic Shot Peening conditions

Material : Steel with Chromium

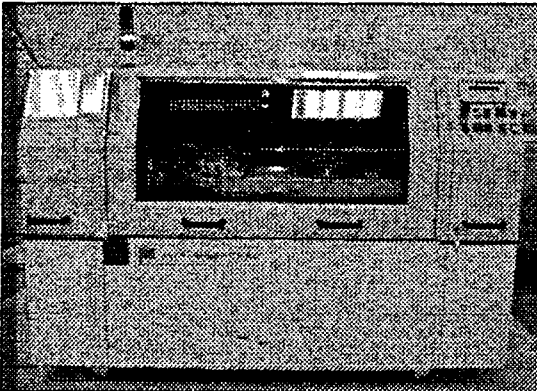


Evolution of hardness from 48 to 56 HRC

7 - Industrial applications.

Following pictures show some industrial applications.

↳ **Integrated automatic shot peening machine for engine parts manufactured by SNECMA.**

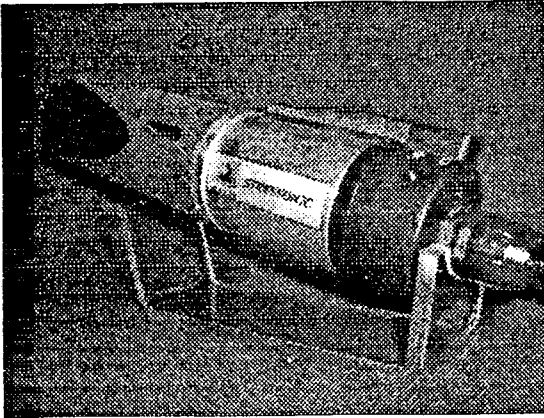


MAIN TOPICS

- Treated part : • Diameter 700 mm
• Height 300 mm
- Treated material : nickel-based material.
- Simultaneous automatic treatment of bores
and faces with complex geometry.
- Floor surface : 2000 x 1 200 mm
- Height: 1 500 mm
- Location : integrated into production line.

- Compact, evolutionary and integrated into production line.
- Easy implementation.
- Programmable automatons.
- Repeatable treatment.
- Safe treatment real time parameters control : - stresses profile control & roughness' control
- Mastered costs and treatment time.
- Environment doesn't need to be protected : shots are confined in a housing.
- Low sound nuisances.

☞ Portable Shot Peening Equipment allowing to work in situ.

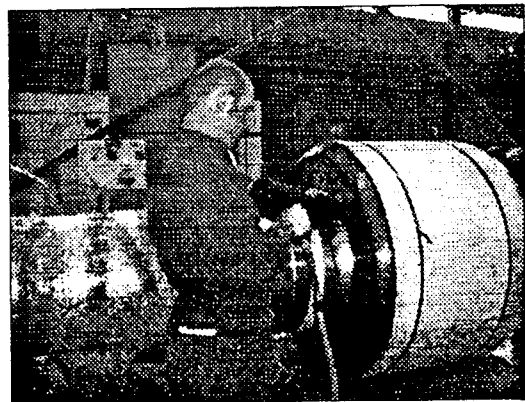


MAIN TOPICS

- Equipment is compact and portable
- Simple to use
- Multiple applications :
 - ☞ Shot Peening touch up in situ.
 - ☞ Field Peening without dismantling.
 - ☞ Stress relief of weld seams.
 - ☞ Peen Forming and straightening

- **Portable Tool :**
 - Weight : 2 to 5 kg
 - Length : 200 to 400 mm, OD : 50 to 80 mm
- **Power Unit :**
 - Portable
 - Reduced overall dimensions
 - Cable between portable tool and power unit 5 to 10 metres
 - Weight : app. 15 kg
- **Low Energy Requested :**
 - Single phase, 220 V 10 A+G.
 - Compressed air may be requested.
- **Advantages :**
 - No spillage of shots - No special environmental protection requested.
 - Wide choice of shots and beads - A few grams of shots are enough so high quality shots may be used at low cost.
 - Parts can be treated in situ, without dismantling.
 - Integrated control supersedes Almen strip control.
 - Low noise level.

☞ Portable Shot Peening Equipment allowing to work in situ.



8 - Conclusion

The STRESSONIC® shot peening is a new surface treatment allowing to increase the resistance to fatigue of the parts which are under high solicitation.

Here are the advantages of the STRESSONIC® process for its user :

- quality of the shot peened areas that improves the resistance to fatigue.
- important depths of compressive stresses.
- perfect control of the shot peening parameters and therefore guarantee of a good repeatability of the treatment.
- savings because there are no consumables (a few grams of balls).
- portable equipment that can be integrated in production line
- possibility to treat every kind of part's shapes.
- possibility to treat part in situ without dismantling ➔ maintenance

Therefore the STRESSONIC® process extends the scope of the shot peening's applications.