EUROPE TECHNOLOGIES
SONATS

RESIDUAL STRESS MEASUREMENT BY X-RAY DIFFRACTION

OBJECTIVES OF RESIDUAL STRESS MEASUREMENT

Product quality and control

- Check the presence of compressive residual stresses
- Identify critical areas with tensile residual stresses
- Quantify the MPa level of residual stresses
- Quality assurance in accordance with technical specifications
- Materials and parts receipt inspection

Process optimization

- Optimize process parameters to reduce residual stresses
- Assess the relevance of a heat treatment during production
- Validate numerical simulations of your processes

Fatigue design improvement and maintenance predictions

- Take into account surface treatments in fatigue design
- Improve lifetime prediction
- Anticipate preventive maintenance operations in critical areas

Founded in 1991, SONATS is an innovative industrial company which is specialized in metal surface treatment and post weld treatment with as core technology the STRESSONIC®, a cold working Ultrasonic Impact Treatment solution (UIT).

Sonats provides a complete range of products and services to extend the fatigue life of mechanical structures and components:

- Ultrasonic Shot Peening equipment
- Ultrasonic Needle Peening equipment (High frequency impact treatment - HFMI)
- Ultrasonic Needle Straightening and Forming equipment
- Peening services (In-house or at customer facilities with portable equipment)
- Engineering services (Residual Stress Measurement and metal process optimization)
- Peening and blasting accessories distribution

06/17

ORIGINS AND IMPORTANCE OF RESIDUAL STRESSES

Origins of residual stresses

Residual stresses are stresses that remain in mechanical parts without the application of external forces. Superficial and bulk residual stress level is the result of mechanical and heat processes from the manufacturing program:

- Casting, forge
- Hot and cold forming
- Additive manufacturing
- Heat treatments
- Mechanical assembly
- Welding
- Cutting
- Rough machining
- Final machining, grinding
- Coating and surface treatments
- Mechanical surface treatments (shot peening, needle peening, roller burnishing, etc.)


Casting, foundry, forge


Welding


Machining, grindind

Importance of residual stresses

- During the part manufacturing program, uncontrolled relaxation of residual stresses (thermal treatment, machining, etc..) may occur and cause severe distortion to the part.
- In operation, these residual stresses are added to external mechanical loads (figure 1). Thus, they do have an influence on the fatigue performance.

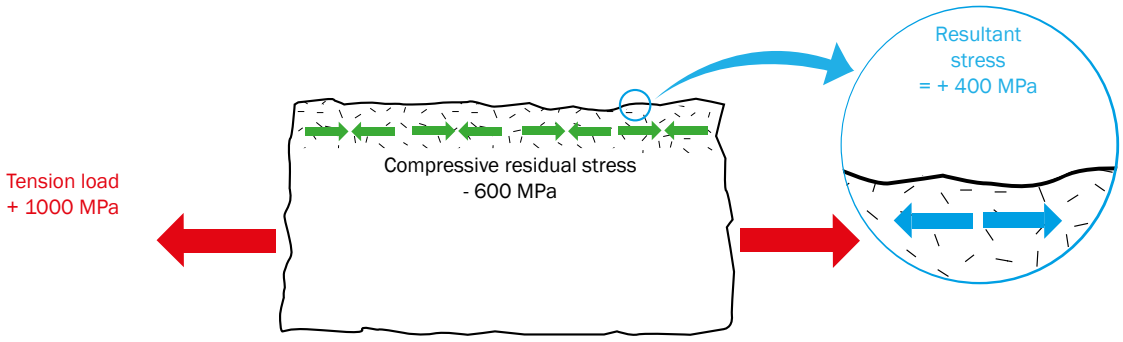

Figure 1 : Addition of in-service loads and residual stresses

Consequences of residual stresses

In most cases, compressive residual stresses at the surface of the part are beneficial and increase resistance to fatigue and Stress Corrosion Cracking - SCC (figure 2). Unintended tensile residual stresses on the opposite are penalizing and may cause premature failure (figure 3).

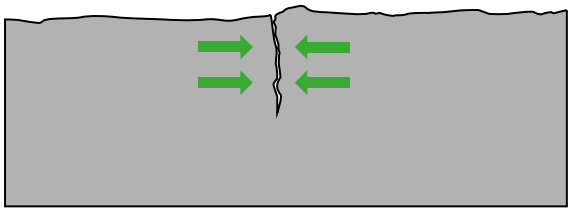

Figure 2 : Compressive residual stresses increasing resistance to fatigue and Stress Corrosion Cracking.

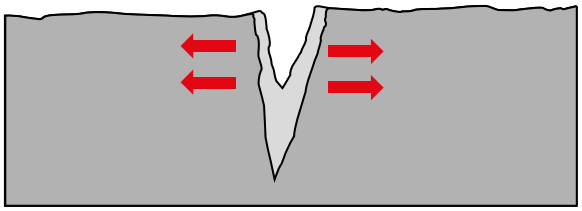

Figure 3 : Penalizing tensile residual stresses leading to a risk of premature failure.

X-RAY DIFFRACTION (XRD) - PRINCIPLE

Principle

The X-ray beam is collimated to the surface of the part. Then, the diffraction angle of re-emitted beams is measured (see Bragg's Law). The measured diffraction angle is directly related to the atomic spacing. Compressive residual stress decreases the inter-atomic spacing. On the opposite, tensile residual stress increases it.

To analyse a stress in a specific direction, the conventional «$\sin^2 \psi$» method is used (described in NF EN 15305 and ASTM E2860 standards). It consists in measuring the evolution of the diffraction angle with respect to the variation of the incident beam angle.

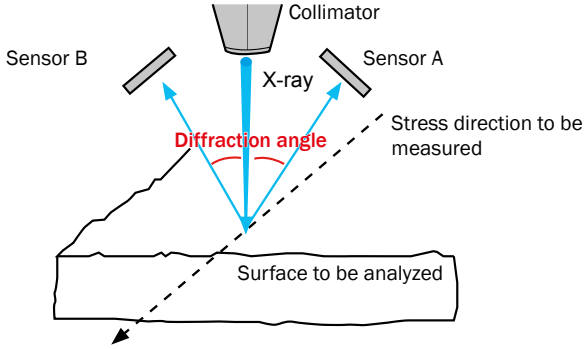

Figure 4: X-Ray diffraction measurement layout (schematic)

Types of analysis we performed...

	Superficial analysis	In-depth analysis
Nature	Non destructive	Semi-destructive
Surface preparation	None *	Electrochemical polishing (= localized material layer removal)**
Analyzed depth	Few microns	Several millimeters
Analyzed materials	Materials : steels, aluminum alloys, nickel alloys, titanium alloys, stainless steels... Ceramics : oxide, nitride, carbide, ...	

* Surface preparation may need cleaning/degreasing.

** In-depth stresses profiles are made by repeating several times XRD method and electrochemical attacks steps.

... with reliable and portative equipments

STRESSTECH Xstress 3000 G2R

- World known equipment dedicated to residual stress analysis
- Portable system for in-lab and in-field services

Experimental parameters

1. Setting up the equipment :
- Manufacturer : StressTech
- Type : Xstress 3000 G2R
- Tension : 28 kV, Power : 6 mA
- Incident radiation available : Cr, Mn, Ti, Cu

2. Equipment control :
- Powder (stresses = 0 MPa) : ferrite, austenite, nickel, titanium
- Shot peened specimens (continuous stresses) : Tensile steel, stainless steel, Inconel, Titanium alloys, Aluminum alloys

3. Acquisition of X-Ray peaks
- Configuration : ψ modified or ω
- ψ angular range : from - 45° to + 45°
- Sensor : CCD (15° ou 30°)

4. Post-processing :
- Input data : in accordance with materials data
- Software: Xtronic
- Peaks position determining : fitting method to be adapted (Gauss, Lorentz, Pearson, multiple peaks, etc.)

APPLICATIONS

Applications examples on various materials and industrial parts

- In-depth stress profiles after shot peening
- Integrity of machined surfaces
- Welding residual stresses thanks to high resolution surface profiling
- Effects of heat treatment temperature on residual stresses
- Measurement of stresses induced by screwing and bolting processes
- Etc...







QUALITY - COST - LEAD-TIME

- ISO 9001 - EN 9100 - NF EN 15305 and ASTM E2860 standards
- Engineers and doctors in material sciences and physical measurments
- Laboratory audited and qualified by major OEMs (aerospace and defense)
- Equipment verification for each step of the process
- Constant follow-up of equipments (control cards)
- Optimized costs and short lead-time

ADVICE AND SUPPORT

First, prior to service, we support you in the issue comprehension of issues and technical specifications. A complete test program is then proposed and detailled.

Our experience and own databases are used to read the results which is a crucial and valuable step of our work in order to define operational outlook.

Metalworking, materials and mechanics is the core expertise of our team. We are your partner and promise to deliver quality results to help you improve your products and processes.




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