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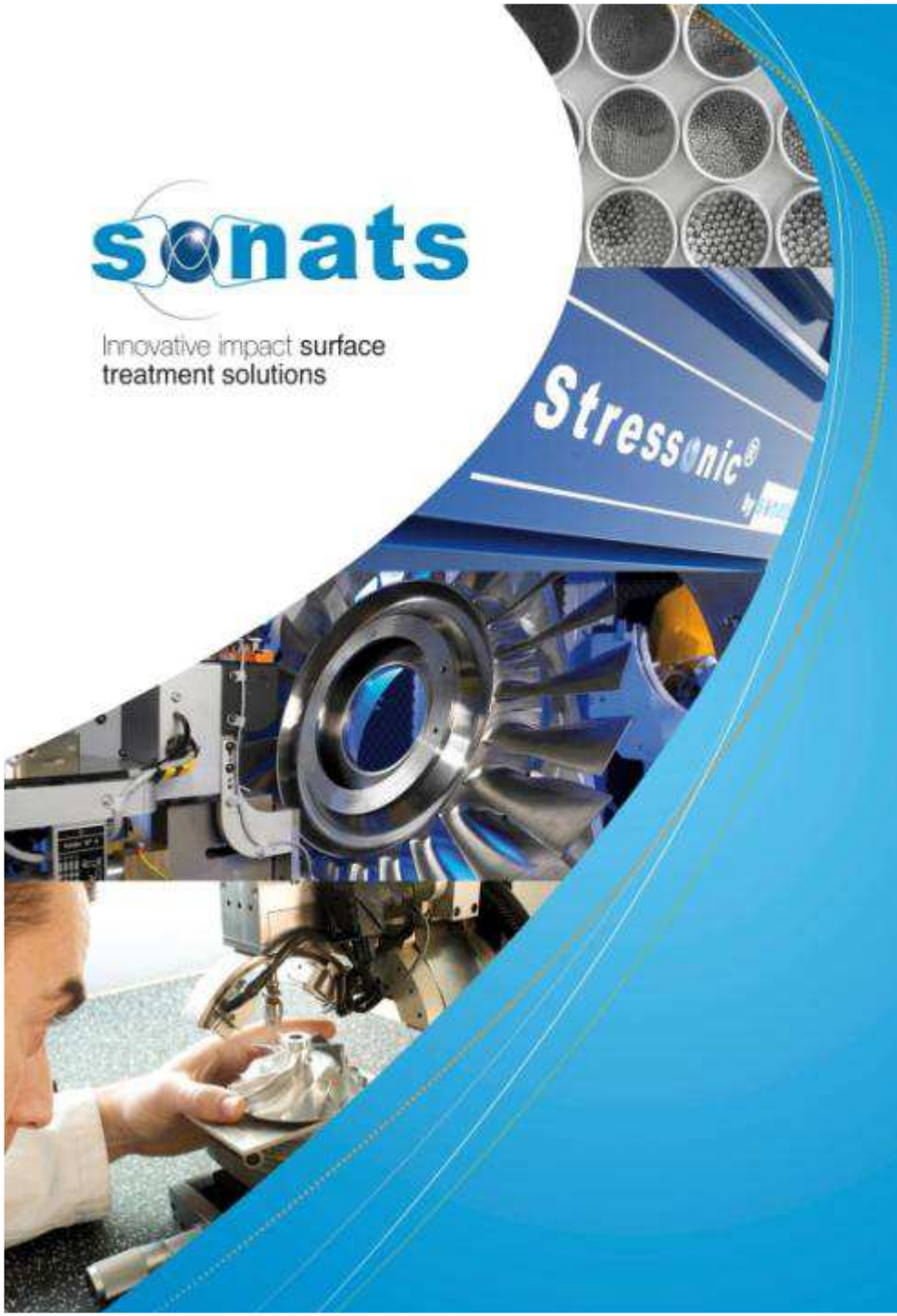
Innovative impact surface treatment solutions



Qualification and Deployment of Ultrasonic Shot Peening System for Production and Repair in Automotive and Aerospace Industries

Hadrien VAUTHENY
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International Sales Engineer

SHTE, Västeras, SWEDEN
September 22th, 2015

Technology Division of Europe Group

Summary

How to control and modify the residual stresses leading to distorsion effect on a critical engine part ?

1. **Introduction : distorsion and residual stress**
2. **X-ray diffraction method for residual stress measurement**
3. **Effect of Machining and heat treament on residual stress**
4. **The interest of Ultrasonic Shot Peening for distorsion control**
5. **Conclusion**

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1. Introduction

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Introduction

SONATS is a private owned company located in Nantes, FRANCE since 1991.

Dedicated to the **Impact Surface Treatment**, SONATS has developped a very wide range of **Services and Equipements** with a Laboratory and Manufacturing facilities :

_ Residual Stress Measurement (RSM) by X-Ray diffraction
_ Ultrasonic Shot Peening Equipement
_ Forming and Straightening Equipement
_ Needle Peening Equipement

=> **One target : Improve the mechanical properties and the fatigue life resistance of metalic parts and structures in any industrial sector.**

Introduction

Rotating parts dedicated to Engine and Transmission with high dynamic and balancing properties in the Automotive and Aerospace industries **are subject to distorsion during and after heat treatments.**

Technical case :

Willing to implement a new design to a Turbo Wheel shaft, an Engine Manufacturer has been subject to a significant decrease in life time of its Turbocharger. Despite a usual mechanical design and controlled heat treatment, distortion of the shaft is leading to miss-alignment and balancing issues causing a quick wear of the system.

Introduction

- **Turbo wheel and shaft for Automotive and Aeronautical Engines**

Manufacturing processes :

- Electron beam welding between steel and Inconel
- Hard turning
- Grinding
- Heat treatment
- Etc.

Inconel wheel ⟷ **Steel shaft**

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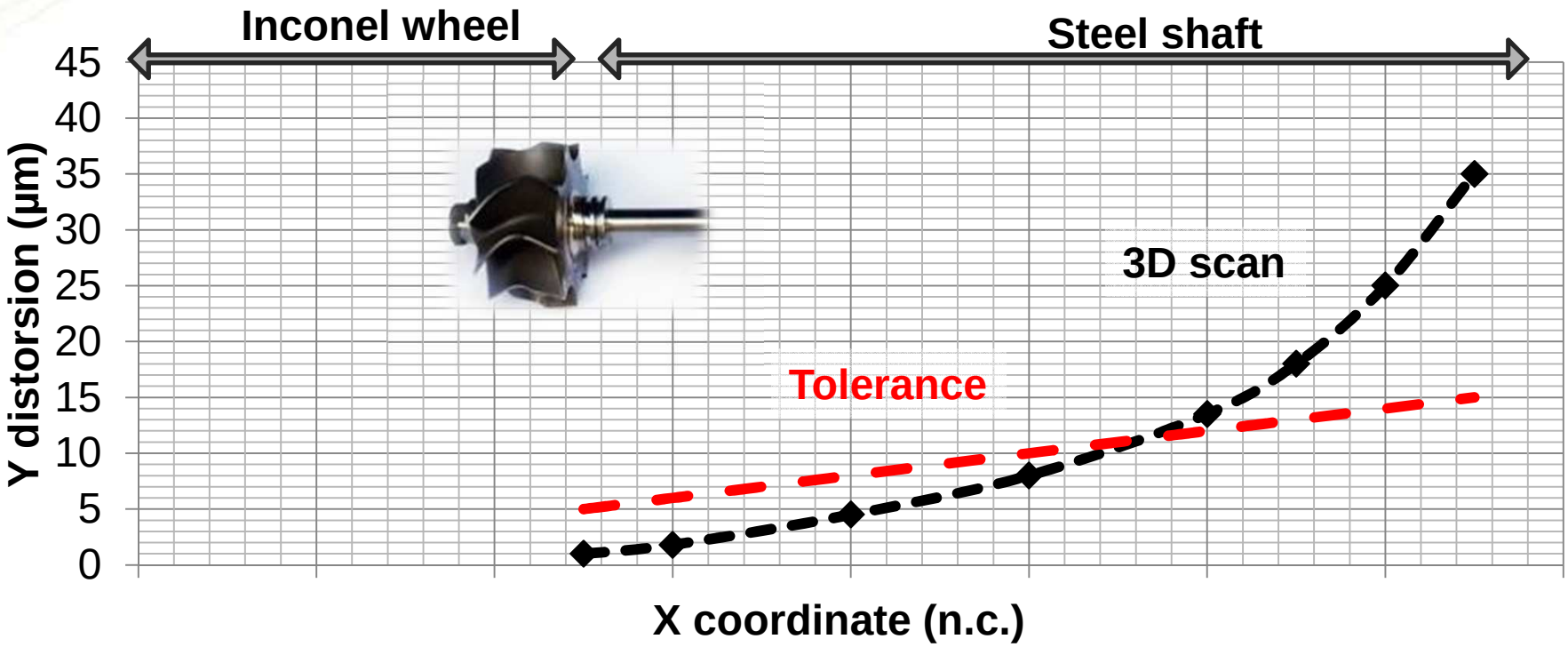
Introduction

When and where does appear distorsion ?



Distorsion may happen :

- after heat treatment
- **after few hours of service → very hard to detect in production**

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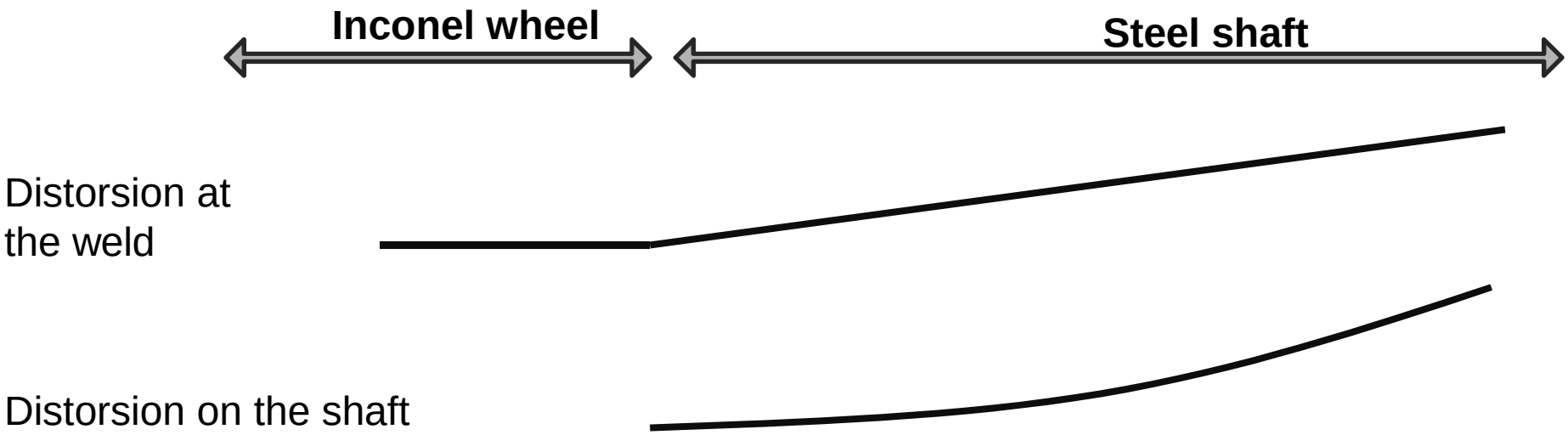
Introduction

Hypothesis : Residual stresses still existing after heat treatment are released in service and lead to material deformation



How to measure and control residual stresses to reduce distorsion?

2. Residual stress measurement method

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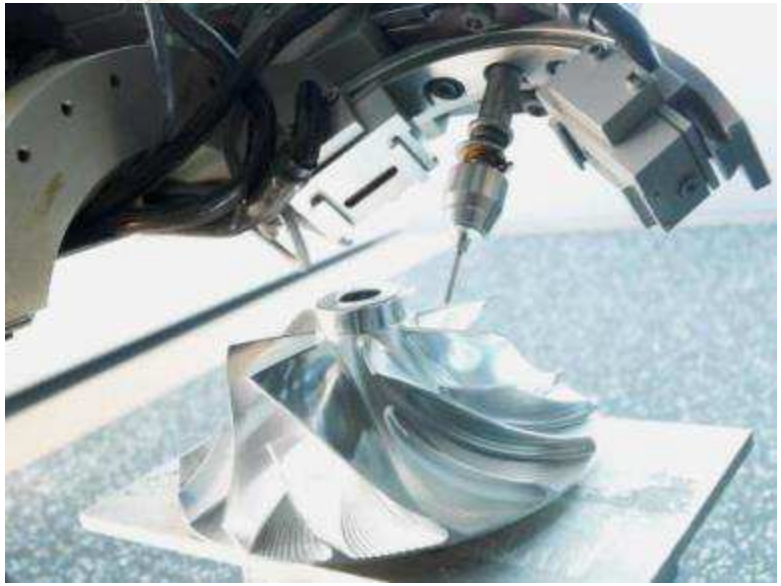
Residual Stresses Measurement Method



X-ray diffraction stress analyzer :

StressTech XSTRESS 3000 G2R (Finland)

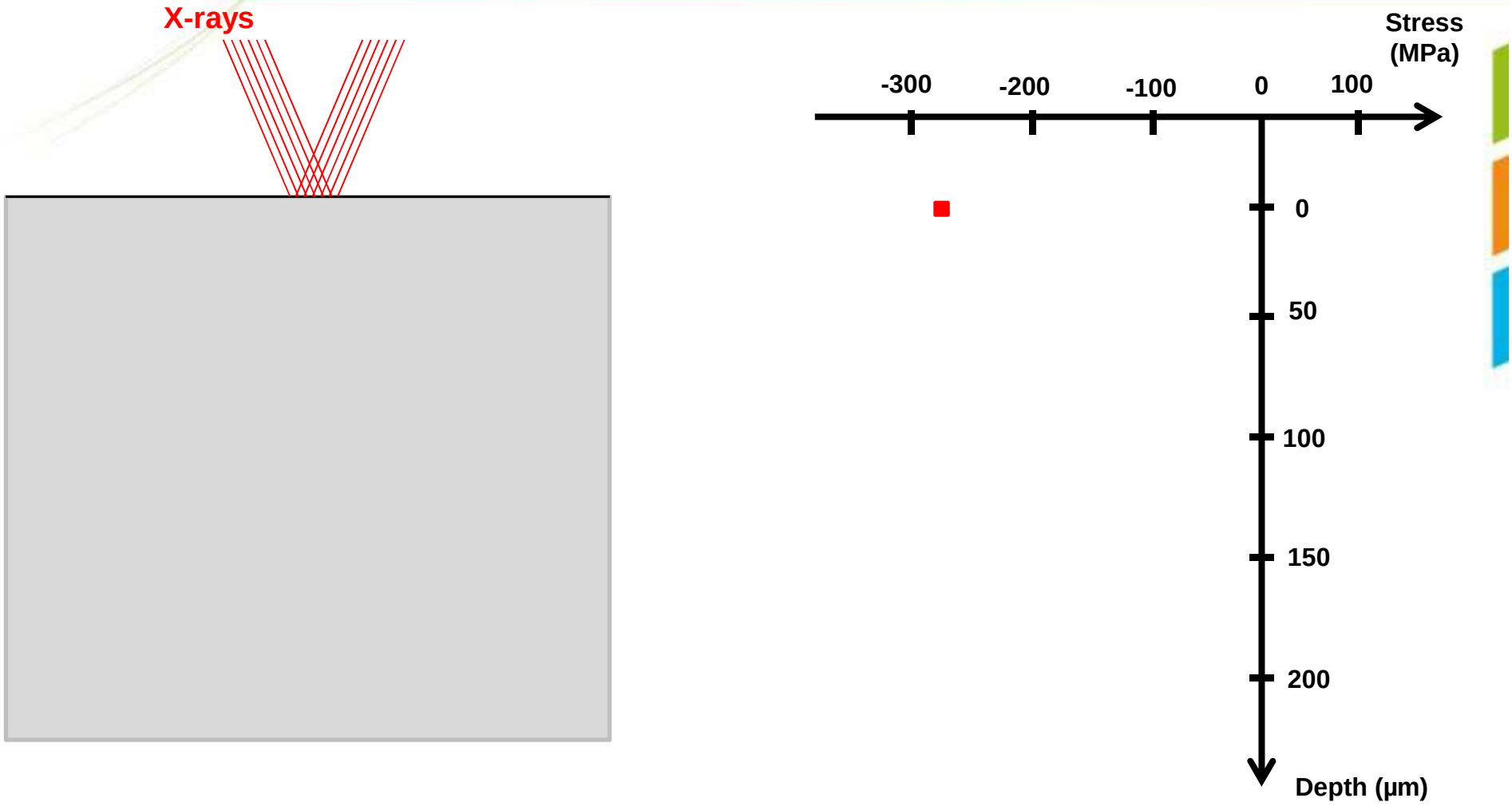
- ✓ High voltage generator
- ✓ Goniometer
- ✓ Sofware

- Superficial measurement, non destructive testing
- In-depth measurement when combined with electrochemical polishing (destructive)
- European standard NF EN 15305
- On metals and ceramics : low alloy steel, stainless steel, Aluminum alloys, titanium alloys, Nickel-base alloys, Inconel, copper, bra advanced lightweight material (metal matrix composite, superalloys, etc.) …
- Limits : very large grains, important crystallographic texture

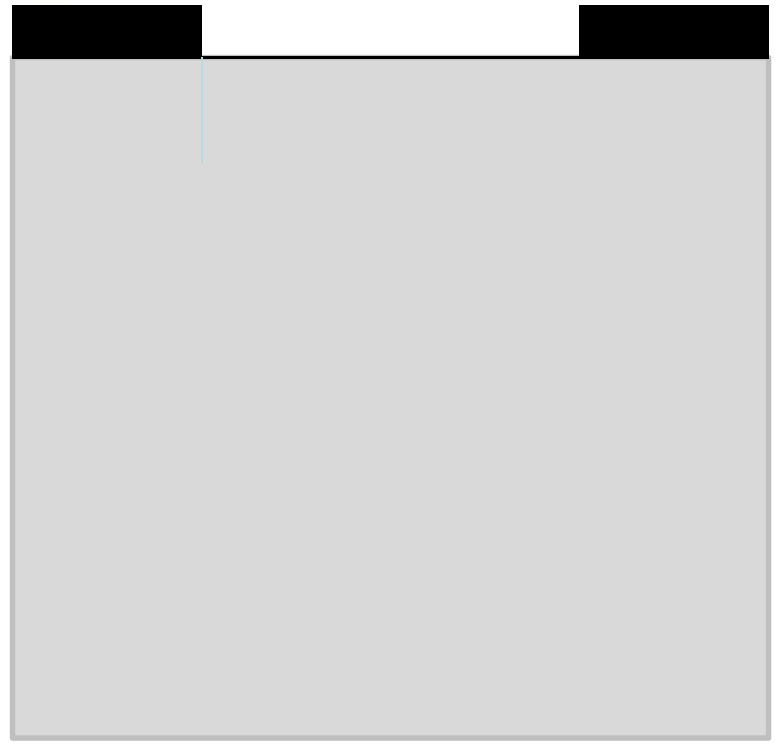
F. Lefebvre, et al., External reference samples for residual stress analysis by X-ray diffraction, Advanced Materials Research **996** (2014), pp 221-227

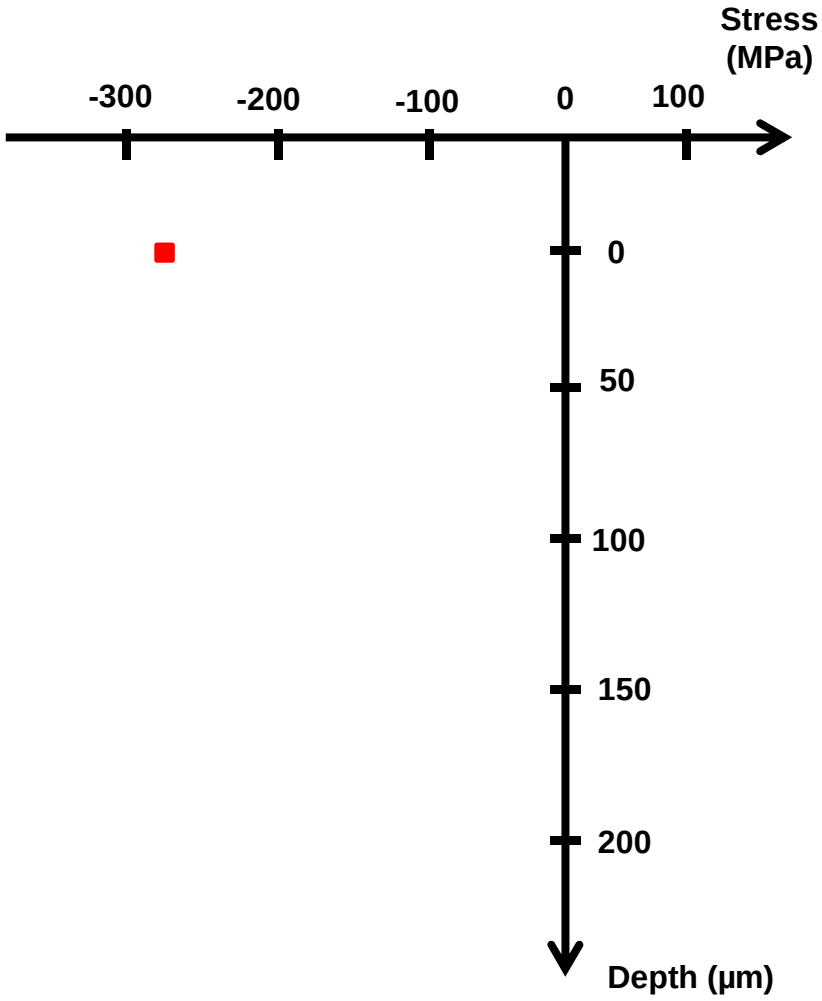
C.E. Murray, I.C. Noyan, Applied and residual stress determination using X-ray diffraction, in: G. S. Schajer (Ed.), Practical Residual Stress Measurement Methods, John Wiley & Sons Ltd., Chichester, 2013, pp. 139-162

Residual Stresses Measurement Method



Residual Stresses Measurement Method





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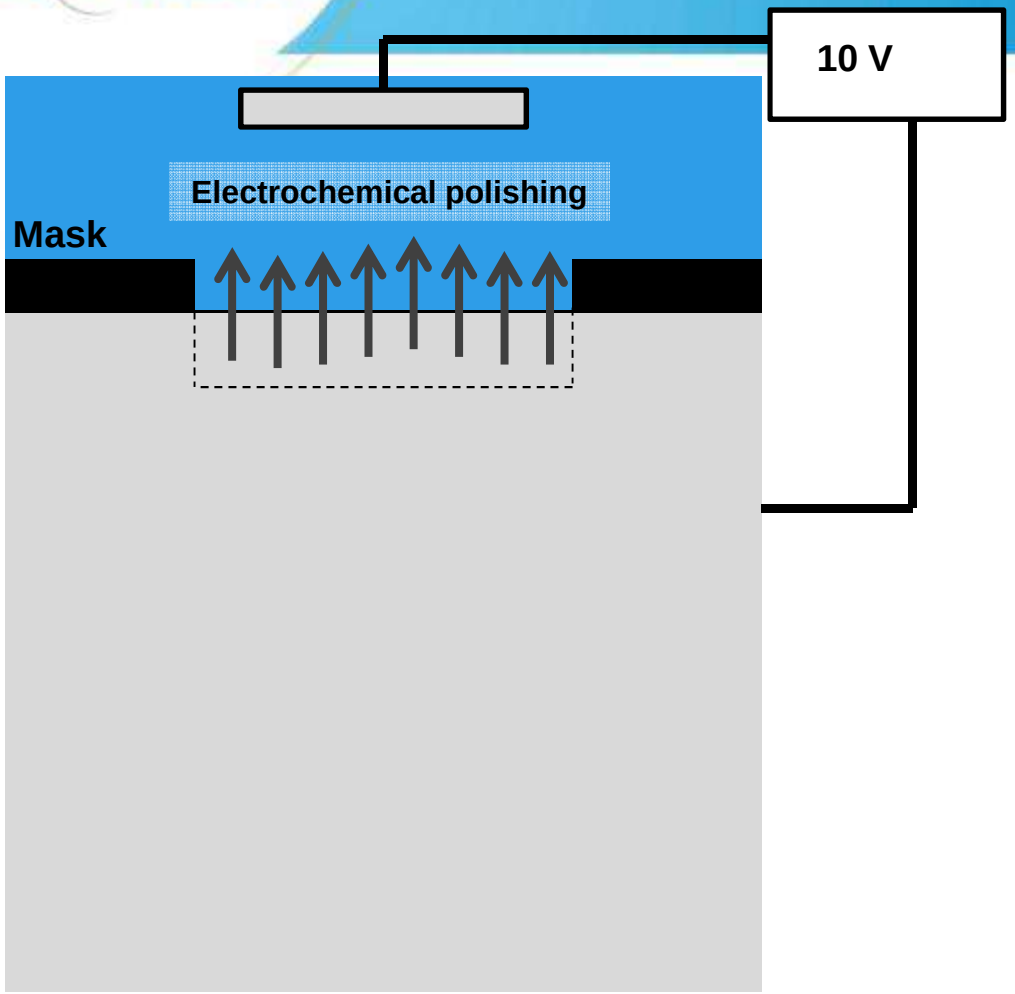

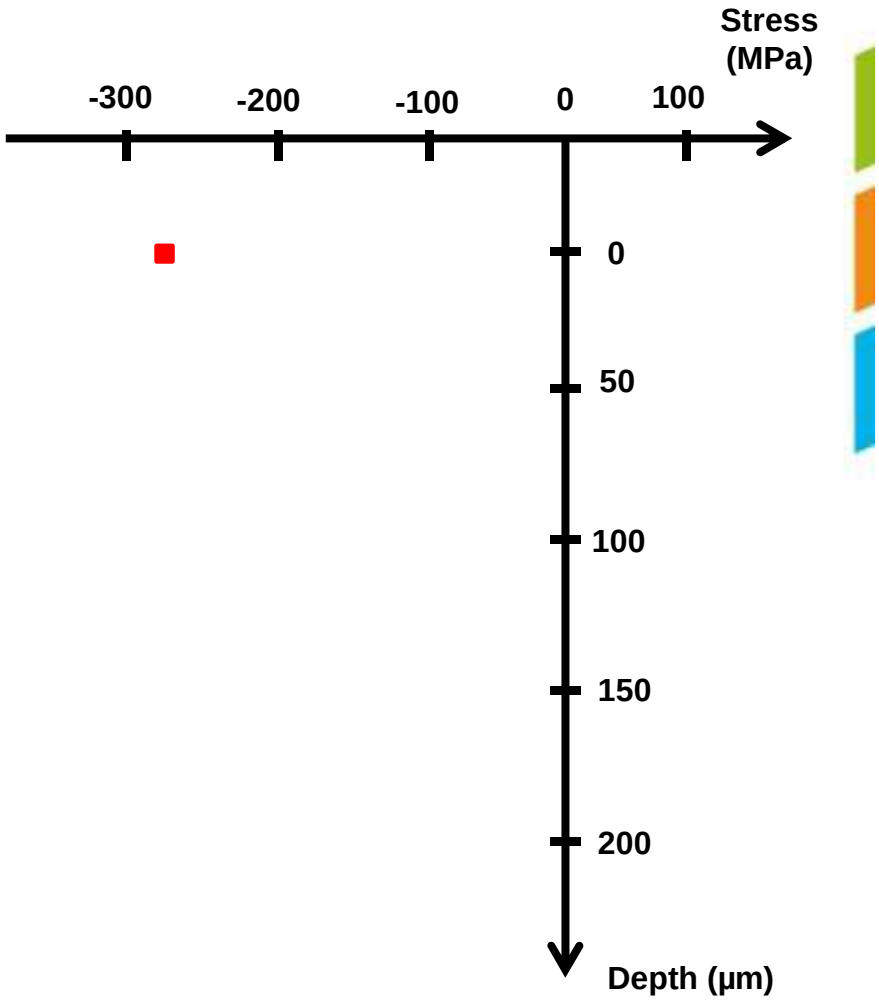

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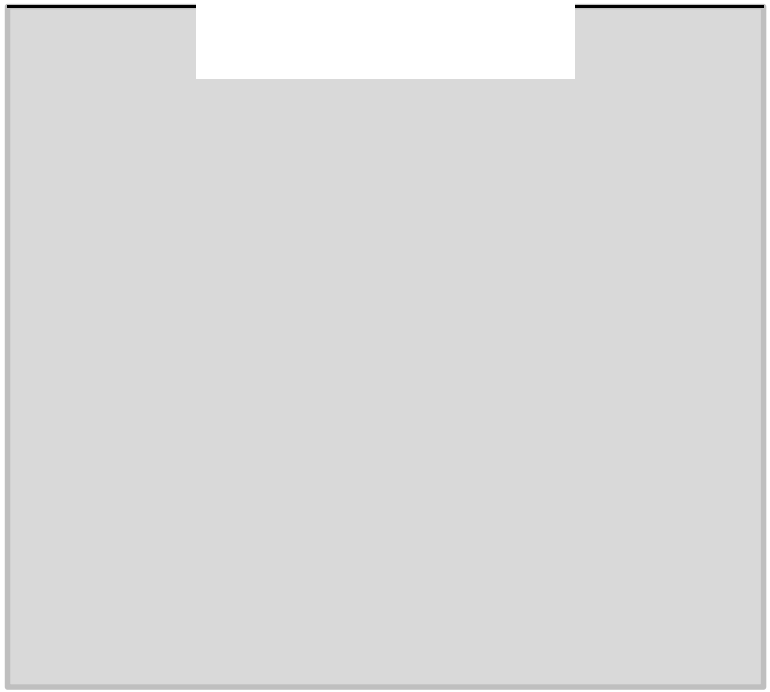
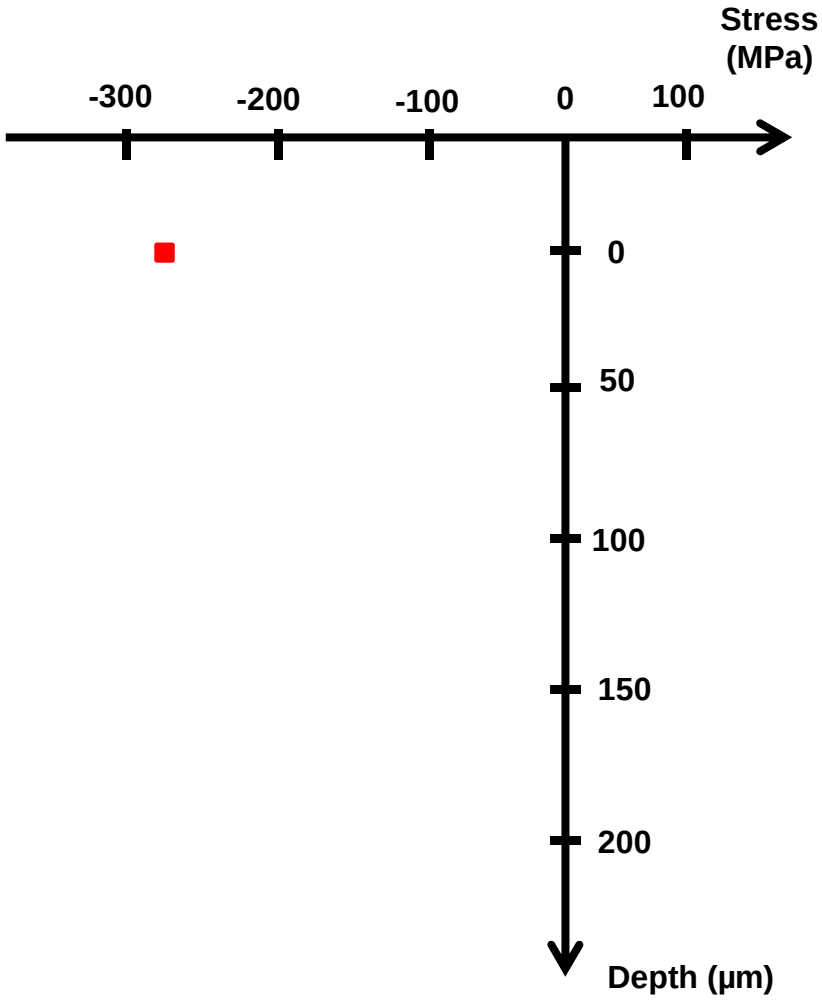
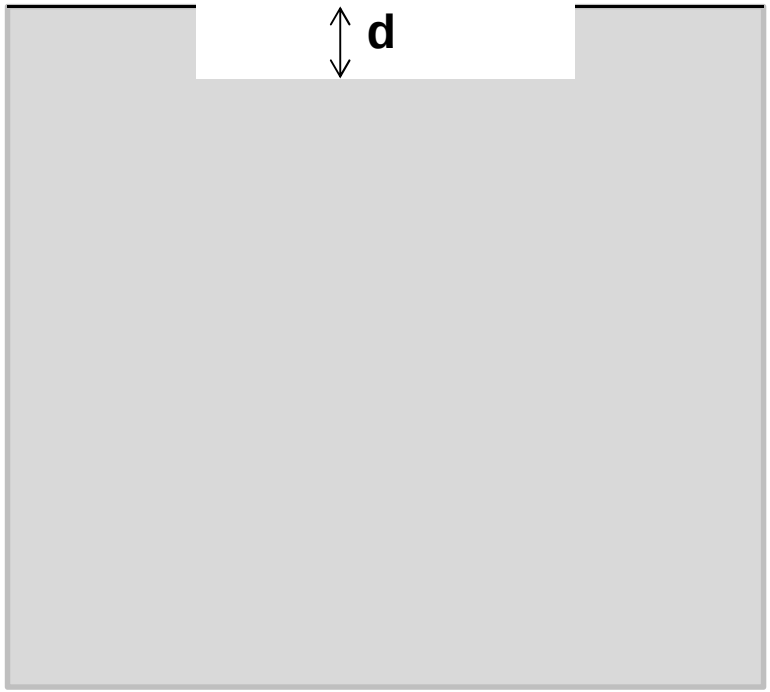
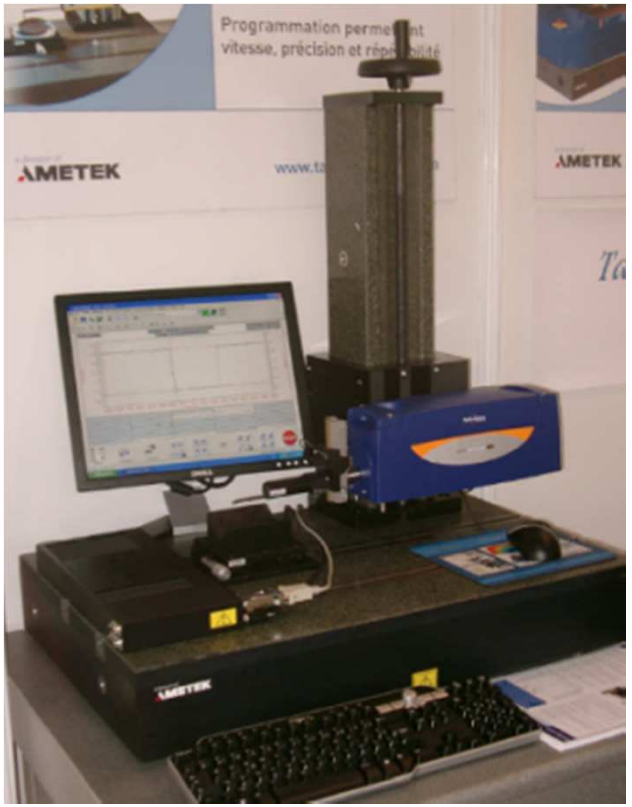




Residual Stresses Measurement Method

Depth measurement : profilometer





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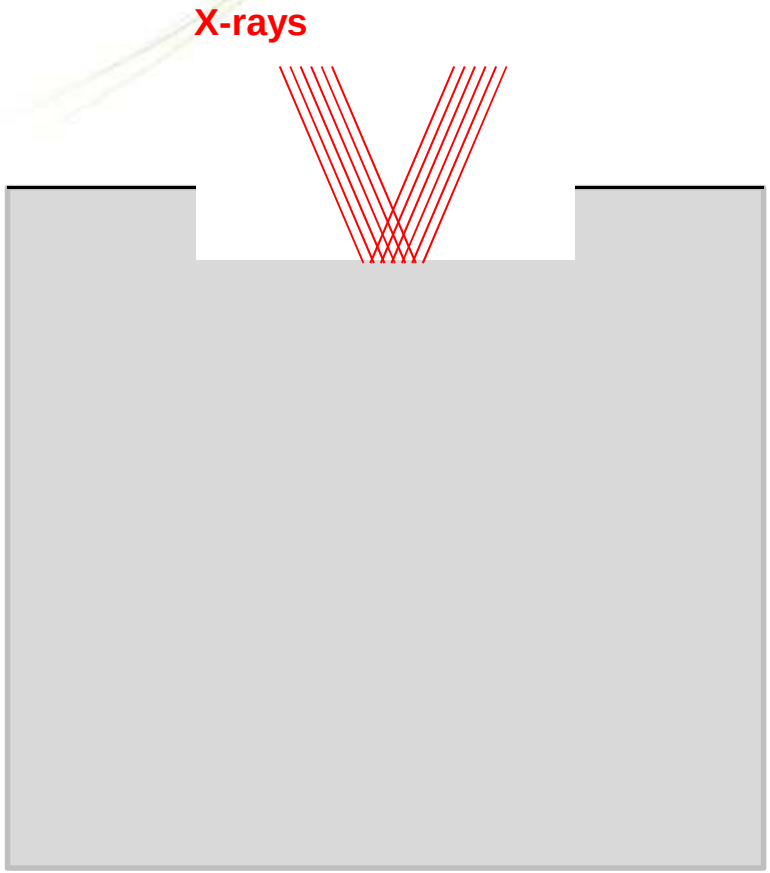
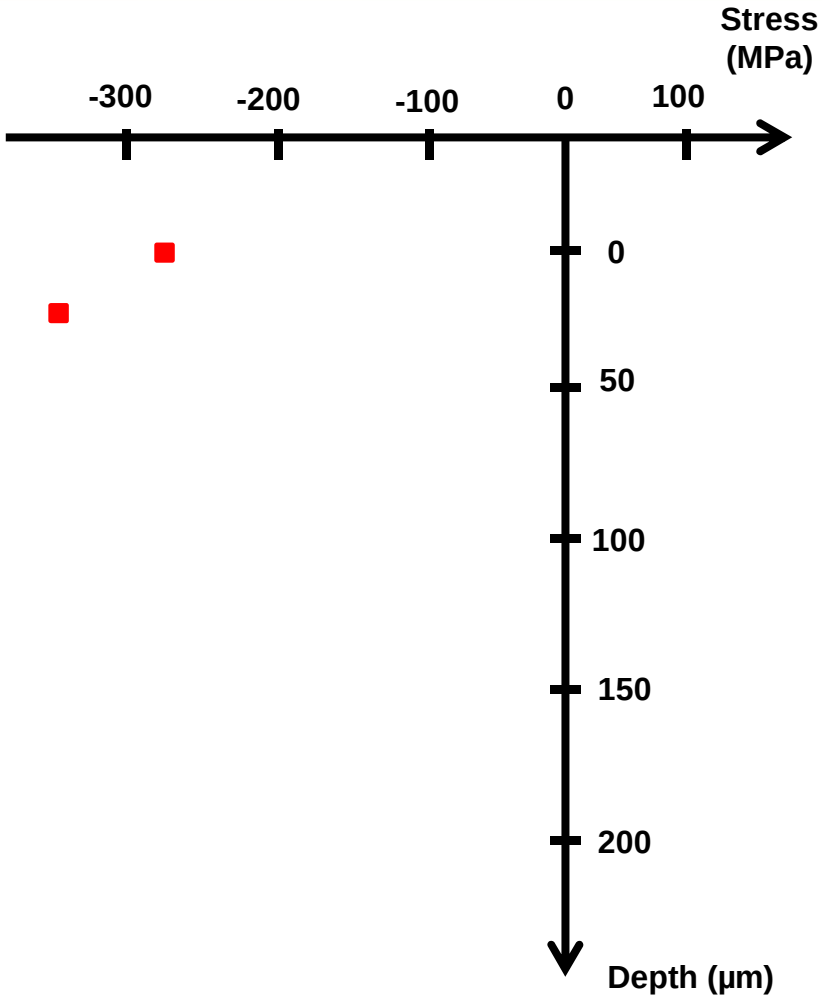
Residual Stresses Measurement Method





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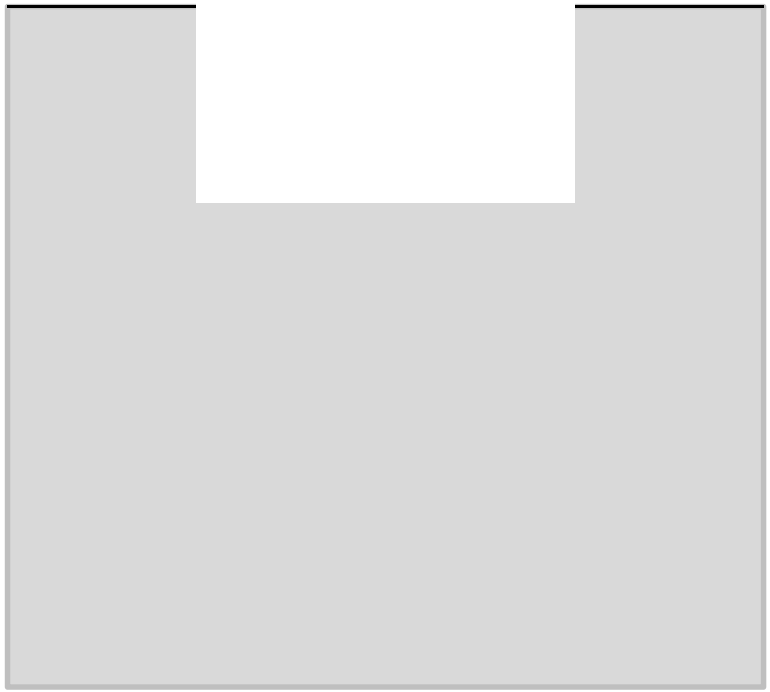

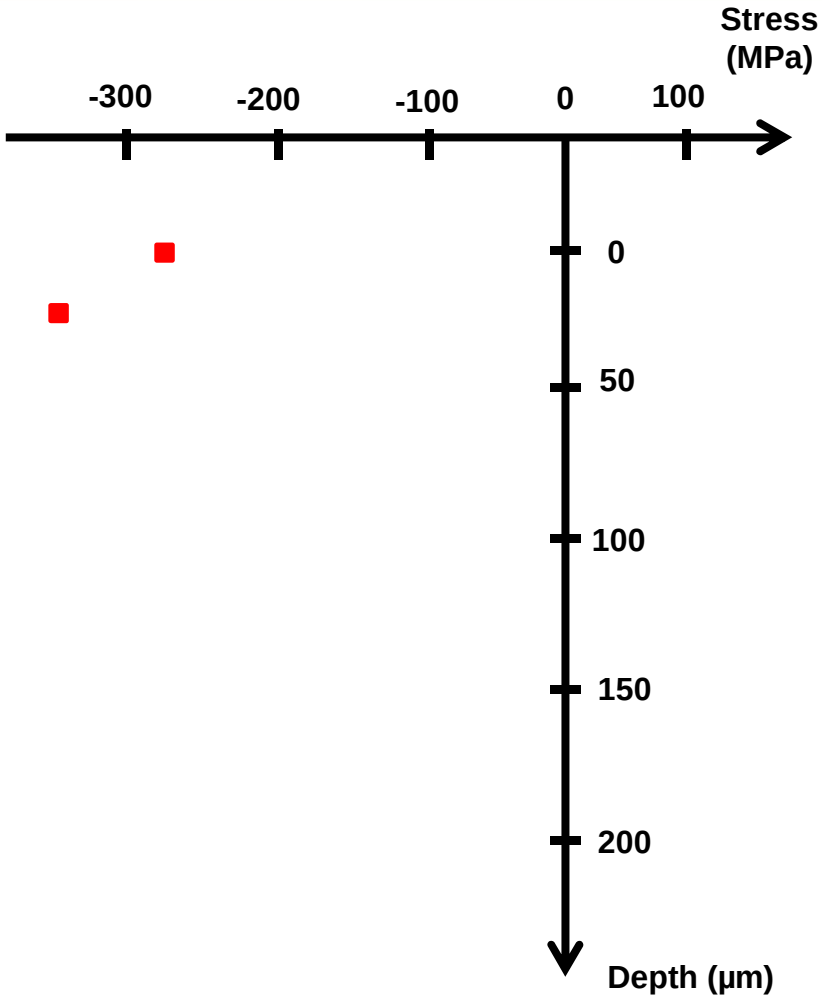

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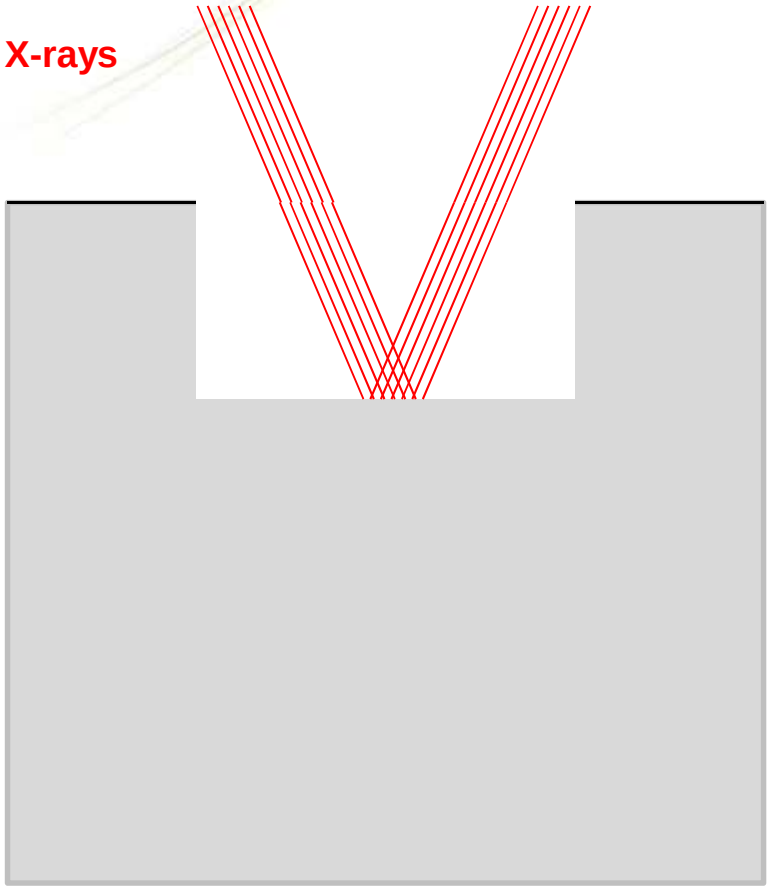

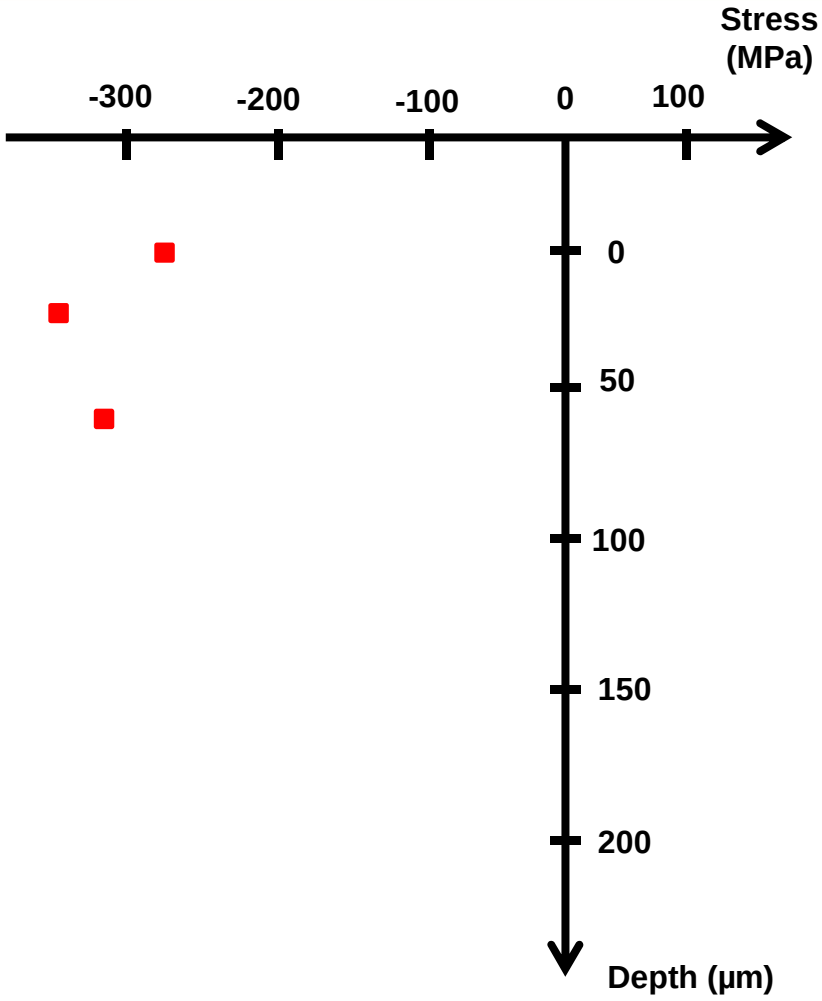

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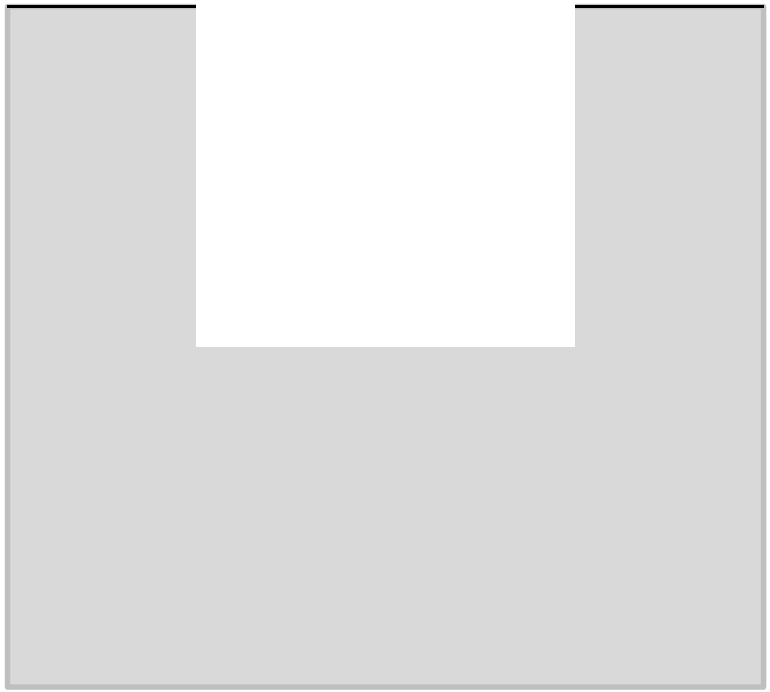
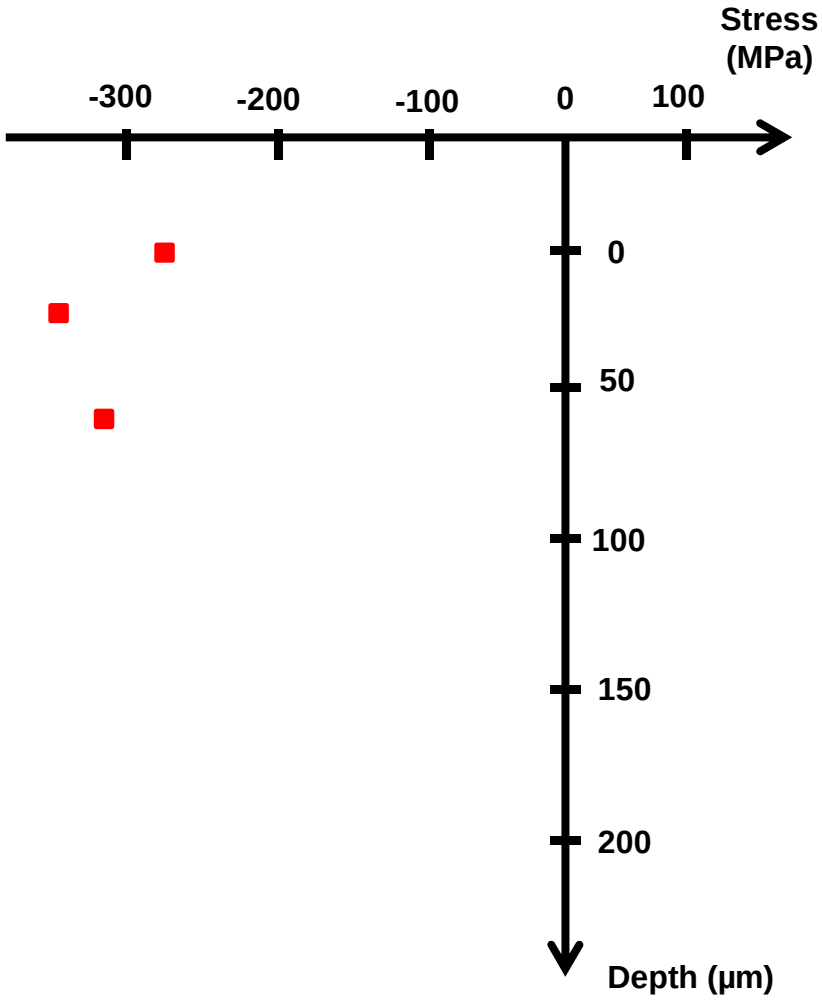
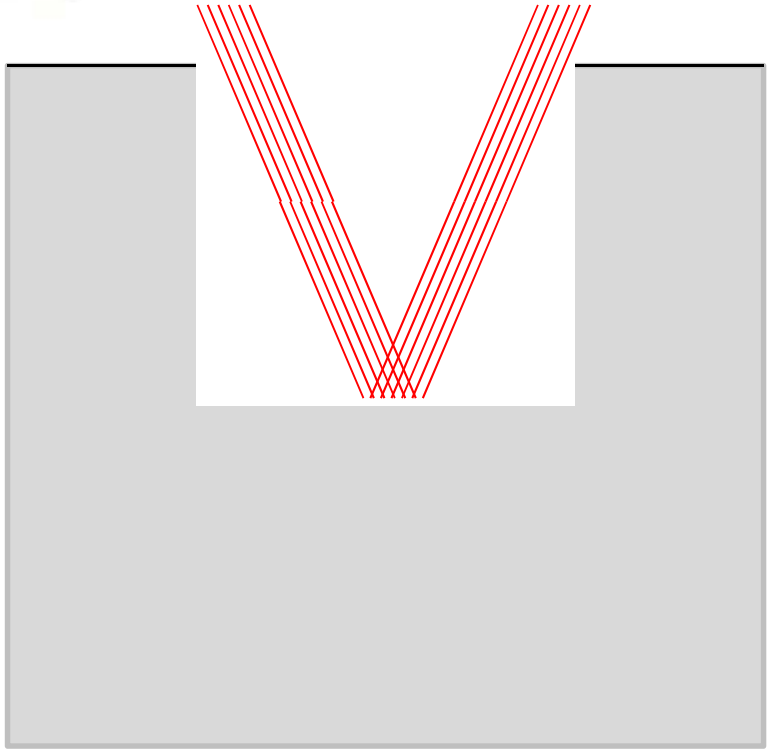
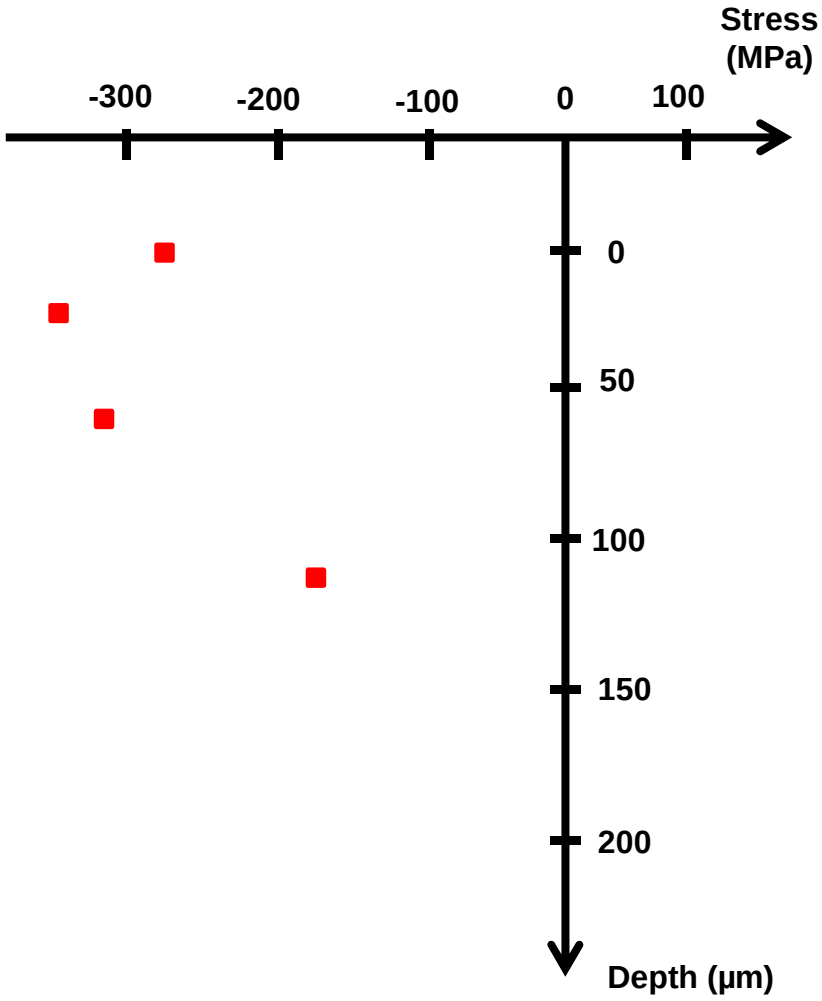




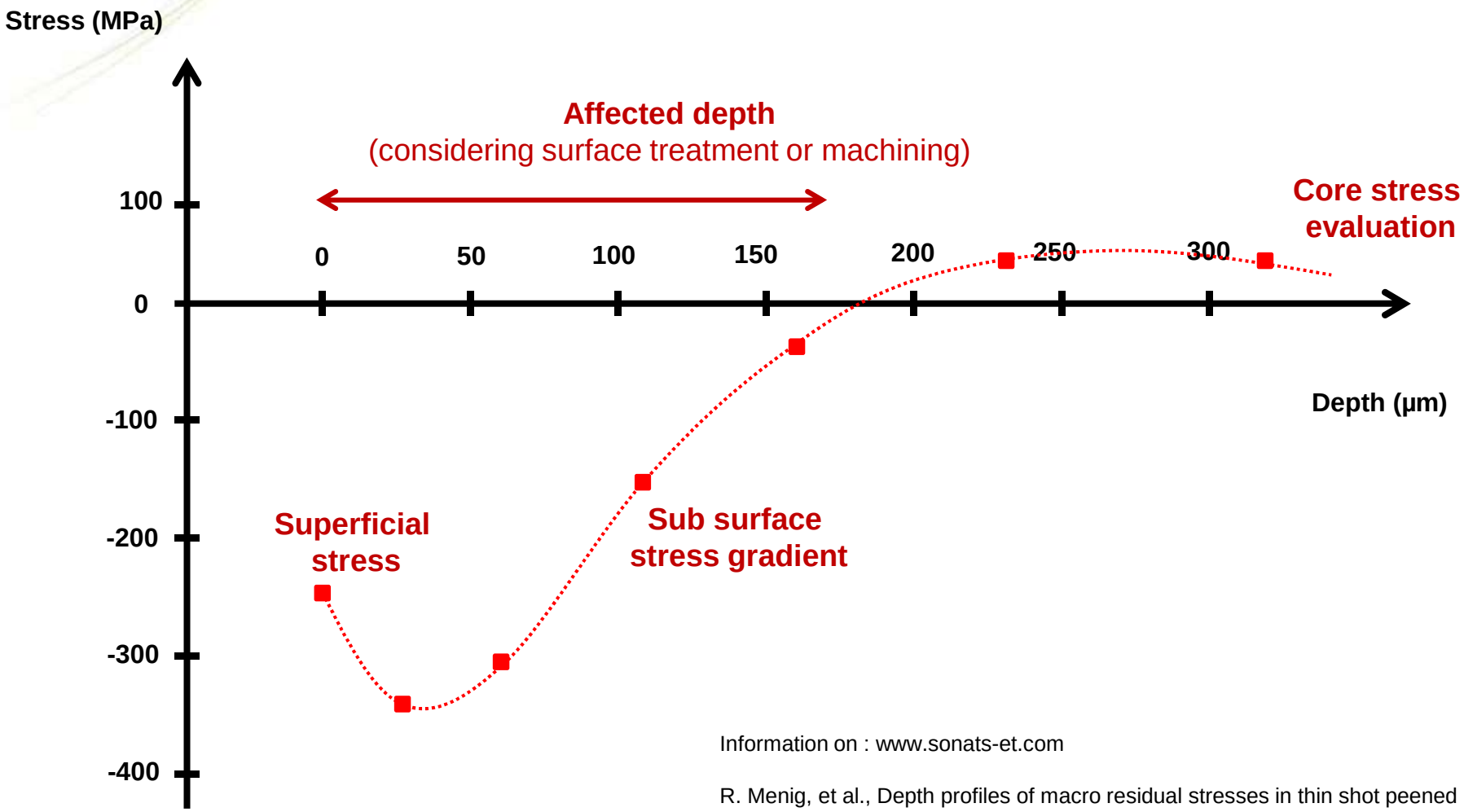
Residual Stresses Measurement Method

X-rays





Residual Stresses Measurement Method



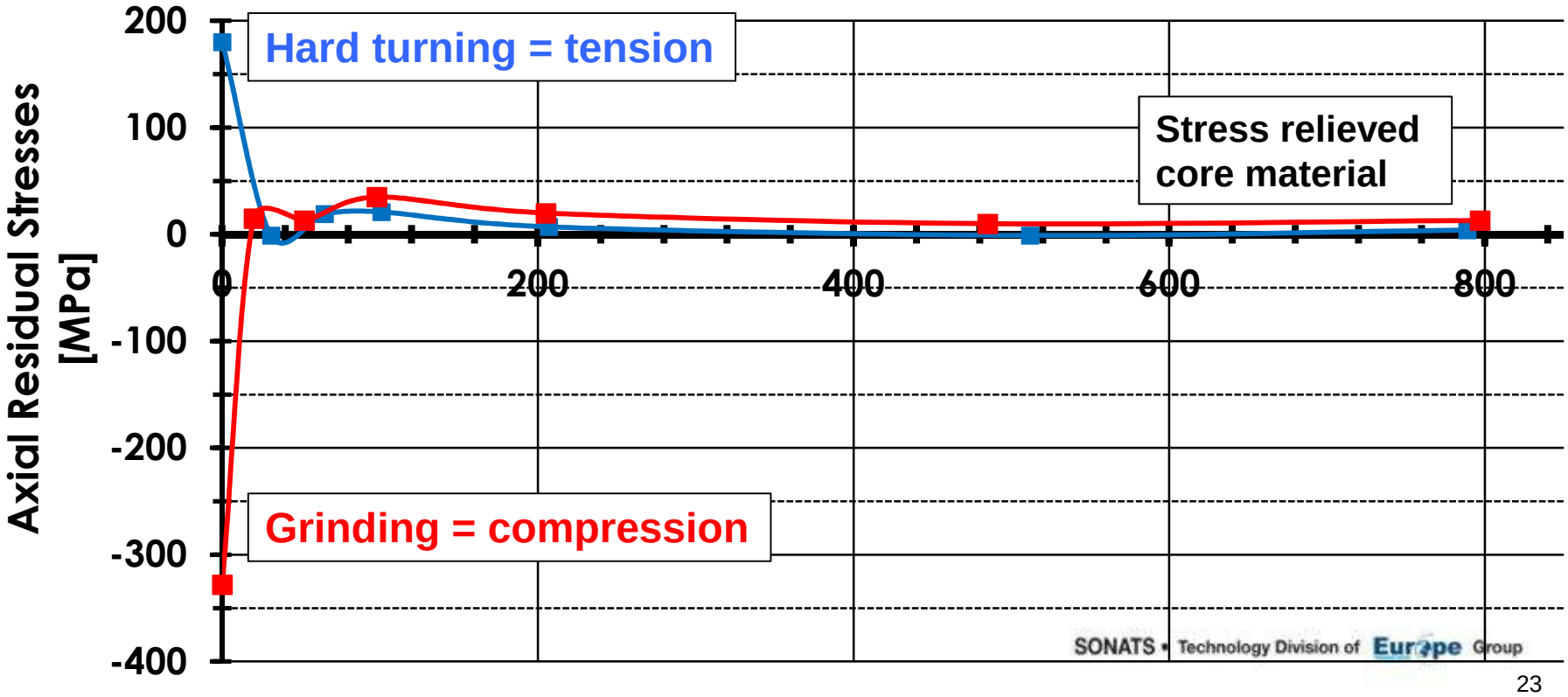
Information on : www.sonats-et.com

R. Menig, et al., Depth profiles of macro residual stresses in thin shot peened steel plates determined by X-ray and neutron diffraction, Scripta Materialia **45** (2001), pp 977-983

3. Effect of heat treatment and machining on residual stress

Effect of heat treatment and machining

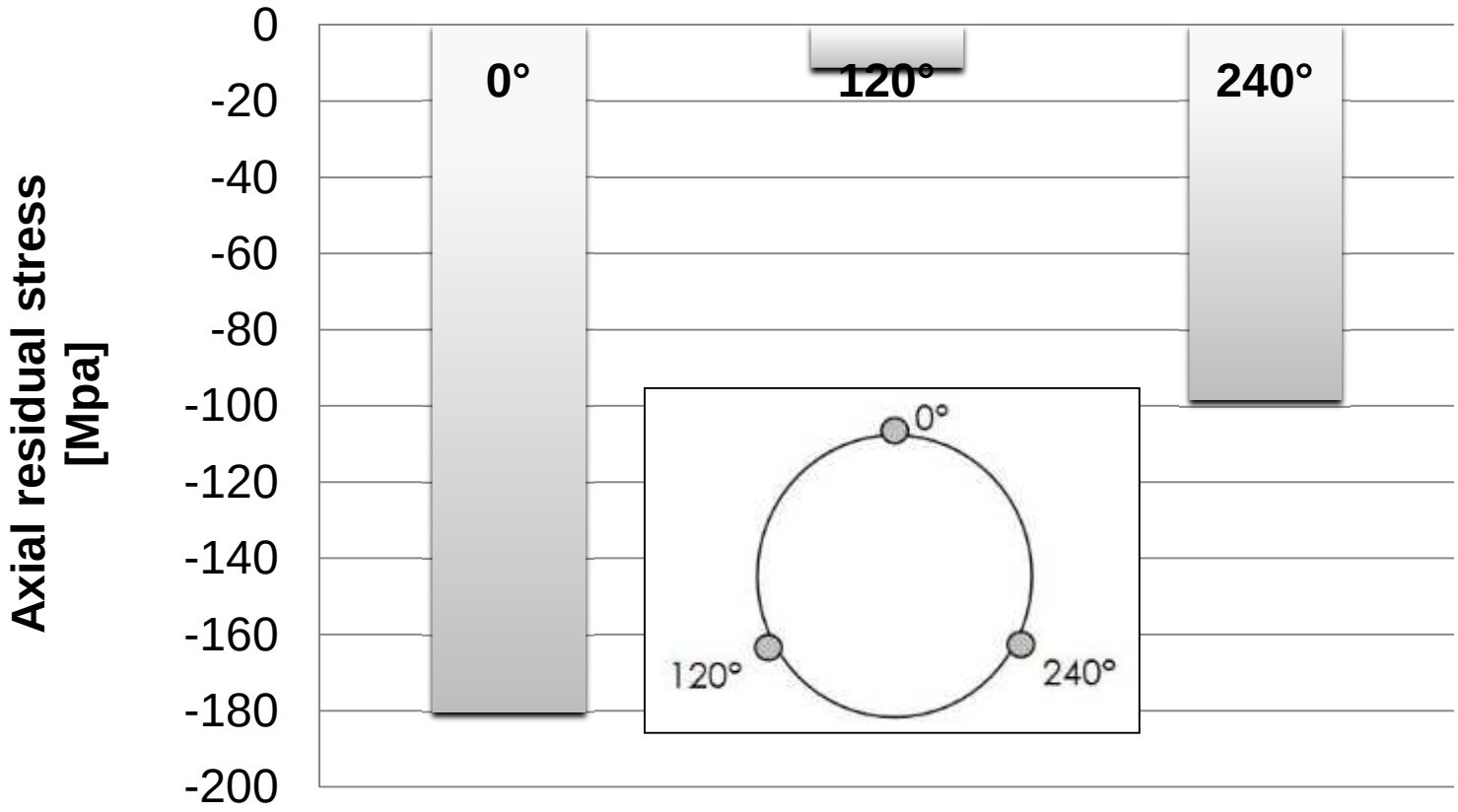
Measurement on the shaft :
Effect of machining operations



Effect of heat treatment and machining

Measurement on the shaft :

Non-symetric distribution of axial residual stress around the circumference



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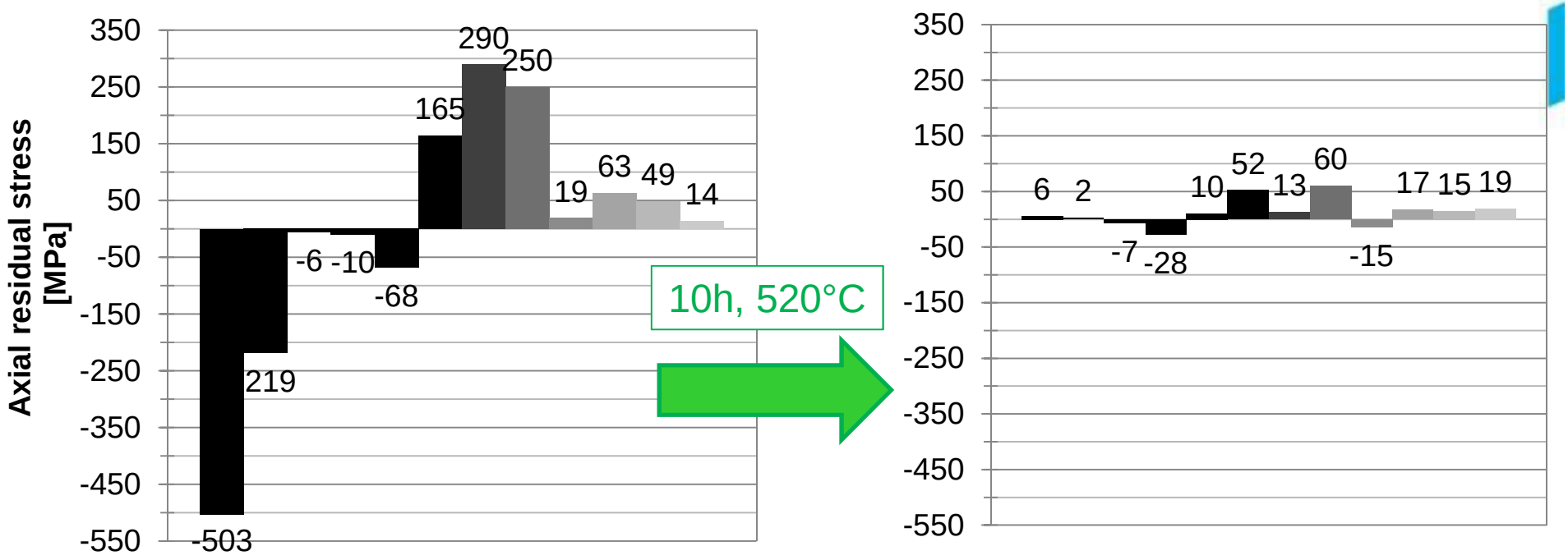
RSM results before and after heat treatment

Effect of the heat treatment

Correct Relaxation of machining-induced superficial stress on the steel shaft



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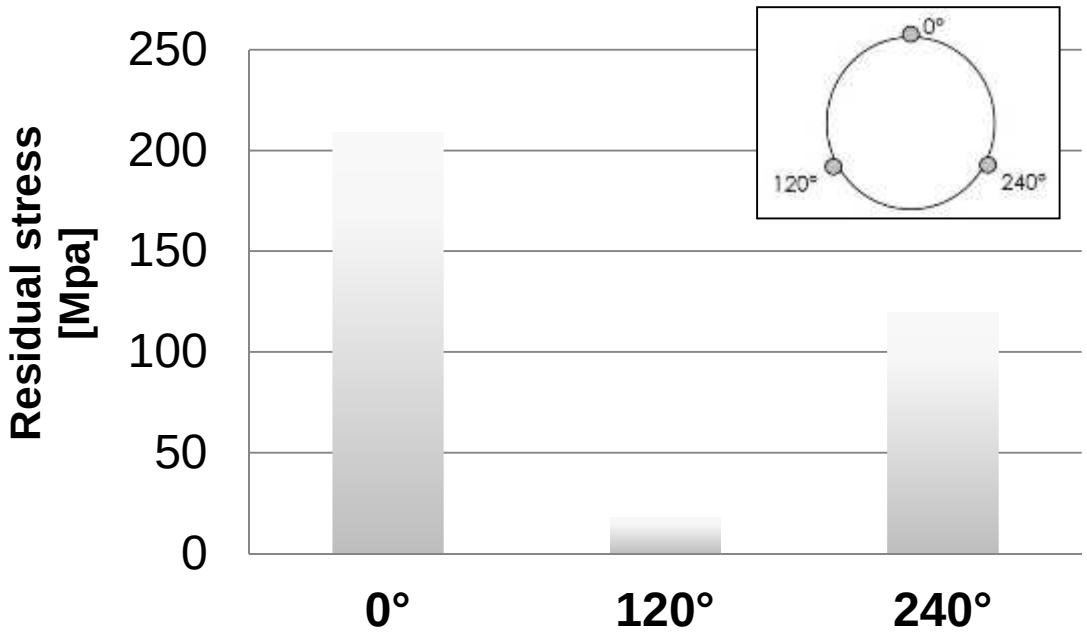
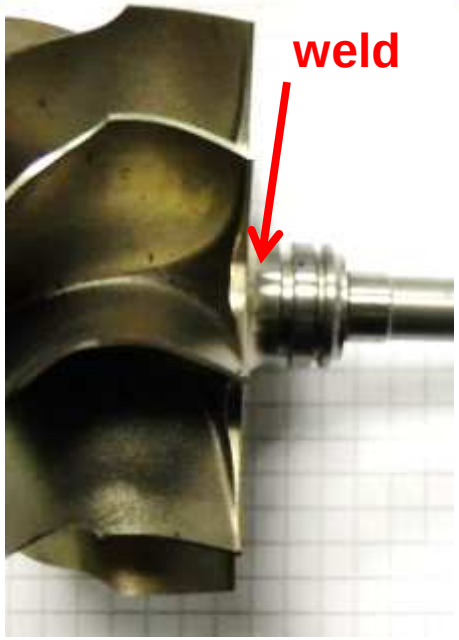
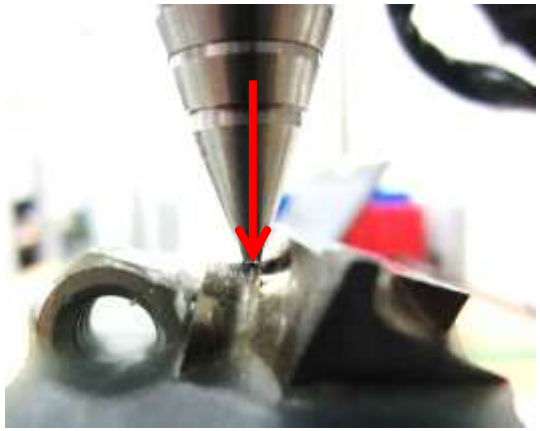
Effect of heat treatment and machining

Measurement on the Inconel-to-steel weld

- Cutting of the part
- Rotation during XRD measurement
- Measurement at the 2mm wide fusion zone







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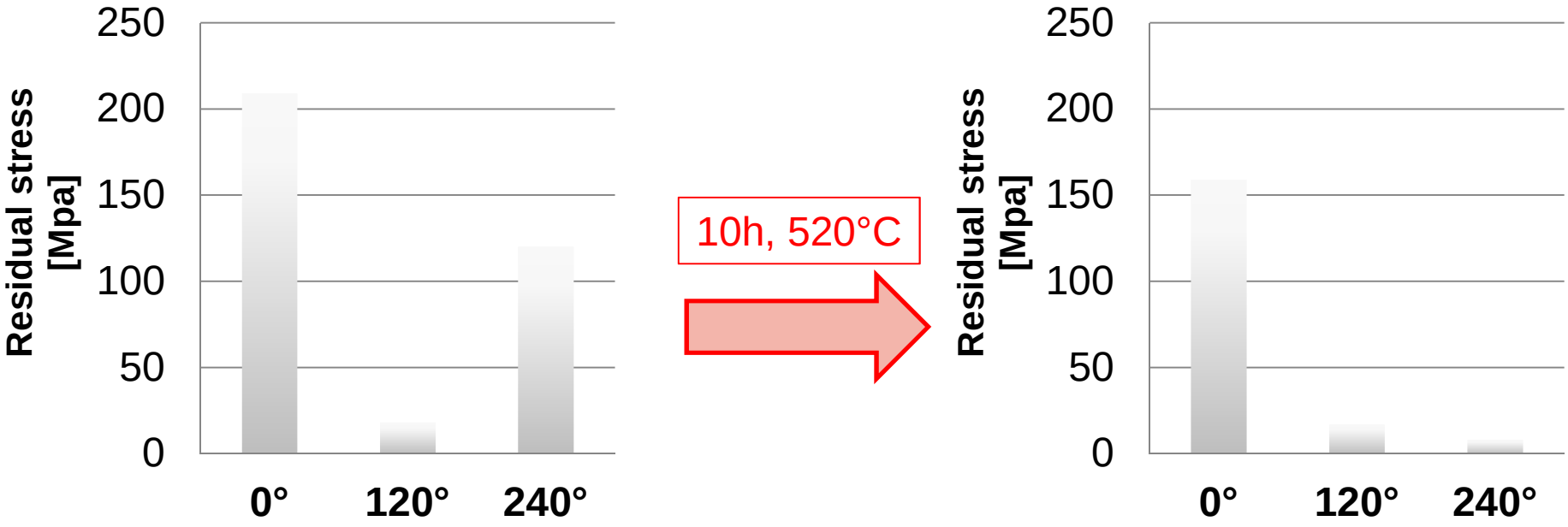
Effect of heat treatment and machining

Effect of the heat treatment

Only partial relief of residual stress at the Inconel-to-steel weld



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Effect of heat treatment and machining

- XRD is able to characterize the residual stress state of the part
- Machining operations induce non-homogeneous superficial residual stress on the steel shaft
- **Heat treatment (520°C) relieves machining-induced residual stress**
- Inconel-to-steel welding induces large and inhomogeneous residual stress at the weld zone
- **In this particular case, Heat treatment (520°C) does not relieve welding residual stress**
- Significant residual stress may be present in the part at the end of the standard manufacturing process

=> Need of an additional process to modify the residual stress distribution and avoid the distorsion phenomenon

4. Ultrasonic shot peening

Ultrasonic shot peening

Ultrasonic Shot peening is a cold working process used to introduce a compressive residual stress layer and modify mechanical properties of metals.
It entails impacting a surface with shot (round metallic, or ceramic particles) with force sufficient to create plastic deformation.

J. Badreddine, et al., Simulation du grenaillage ultrason pour des pièces à géométries complexes, CSMA 2013 (2013)

J. Badreddine, et al., CAD based simulation of ultrasonic shot peening process, International Design Conference , Dubrovnik, Croatia, 2013

Ultrasonic shot peening

Ultrasonic Shot Peening will modify the part :

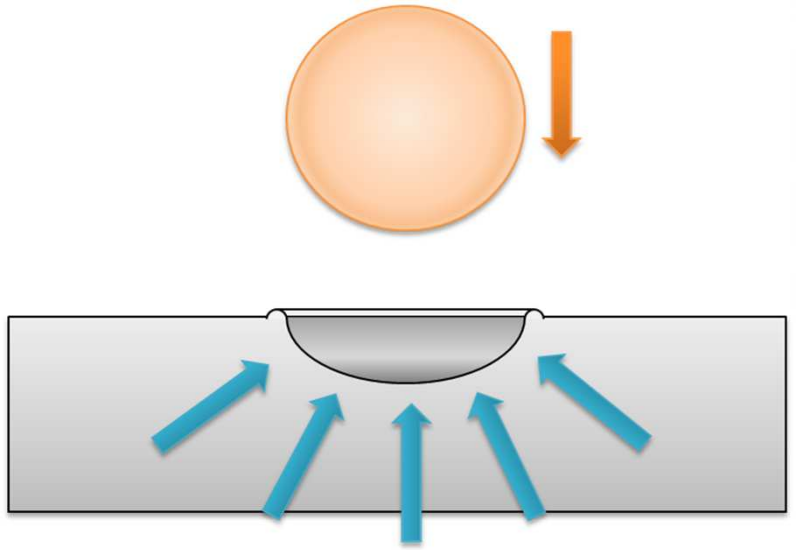
_ localy (specific and targeted areas)

_ with control (real time monitoring of the process) and perfect repeatability

_ introducing **homogenous** compressive stresses

_ monitoring the roughness (increase or decrease after treatment according to the media size)

_ Increasing resitance to fatigue and cycle loadings



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5. Conclusion

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Conclusion

Turbo wheel case shows :

- Industrial issue for a critical engine part
- Identification of root causes in the manufacturing process
- Method of measurement of the residual stresses, main root cause of distorsion in this case.
- Identification of the critical areas of the part
- Quantification and validation of the heat treatment effects
- Additionnal process and complementary solution for homogeneous stress distribution in the part

The USP process :

- Is an high potential method for part quality improvement
- Is used in the aerospacial industry since 1990
- Today under depoyement in the automotive, energy, spatial, infrastructure industries

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