SINT Technology

Measurement of Residual Stresses

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What are residual stresses and how are they caused

All stresses that exist in materials, also without the application of any external loads, are termed residual stresses. Residual stresses can originally exist in a component and naturally add to stresses induced by applied loads.

As a result, residual stresses influence the behaviour of mechanical components and can impair the structural and dimensional stability, as well as the fatigue and fracture resistance of components. A residual tensile stress actually facilitates crack propagation and therefore reduces the fatigue life of a mechanical component.

Residual stresses limit the loading capacity and safety of mechanical components during operation and in certain circumstances it is necessary to be able to quantify those stresses.

In other instances, residual stresses are actually desired. Turbine blades and other metal components are often made with residual stresses to limit cracking and fatigue. In these cases, strong controls and careful calibrations are performed to determine the desired level of stress during the production process.

Residual stresses can be caused by the following main factors:

- Non-uniform heating or cooling of a component during manufacturing and fabricating processes (casting, welding, molding and heat treatment process)
- Machining processes to remove shavings or plastic deformation (turning, milling and forging)
- Through or surface heat treatments (tempering, nitriding and cementation)
- Surface treatments (shot peening and sand-blasting

The study and measurement of residual stresses are therefore crucial in mechanical design engineering for preventing failures, and in some cases even disasters.

Typical application fields of residual stress

Aerospace industry (airplane and aerospace applications)

Automotive industry (series production, sport races and competitions)

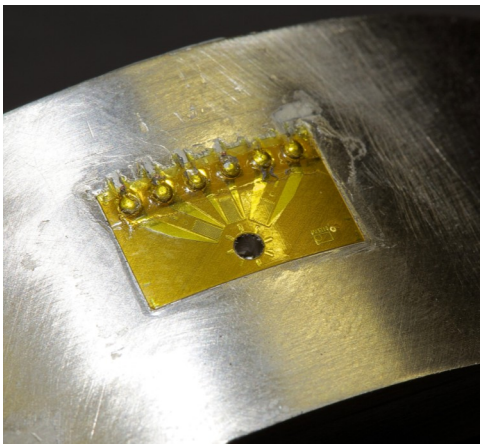
Energy production (steam, wind and nuclear power plants)

Oil and Gas (compressor and turbine parts)

Railway production (wheels and railways samples)

Production control (quality control of the surface and heat treatment)

Strain gage methods for residual stress measurement



A strain gage can be used for a great variety of residual stress measurements.

Many methods exist for the measurement of residual stresses in engineering applications. The method used for the residual stress measurements works on the principle of removing material from the component to release stresses: after this operation the stress equilibrium is modified and one or more strain gages, placed in the measurement area, acquire the strain values needed for the new equilibrium of the workpiece.

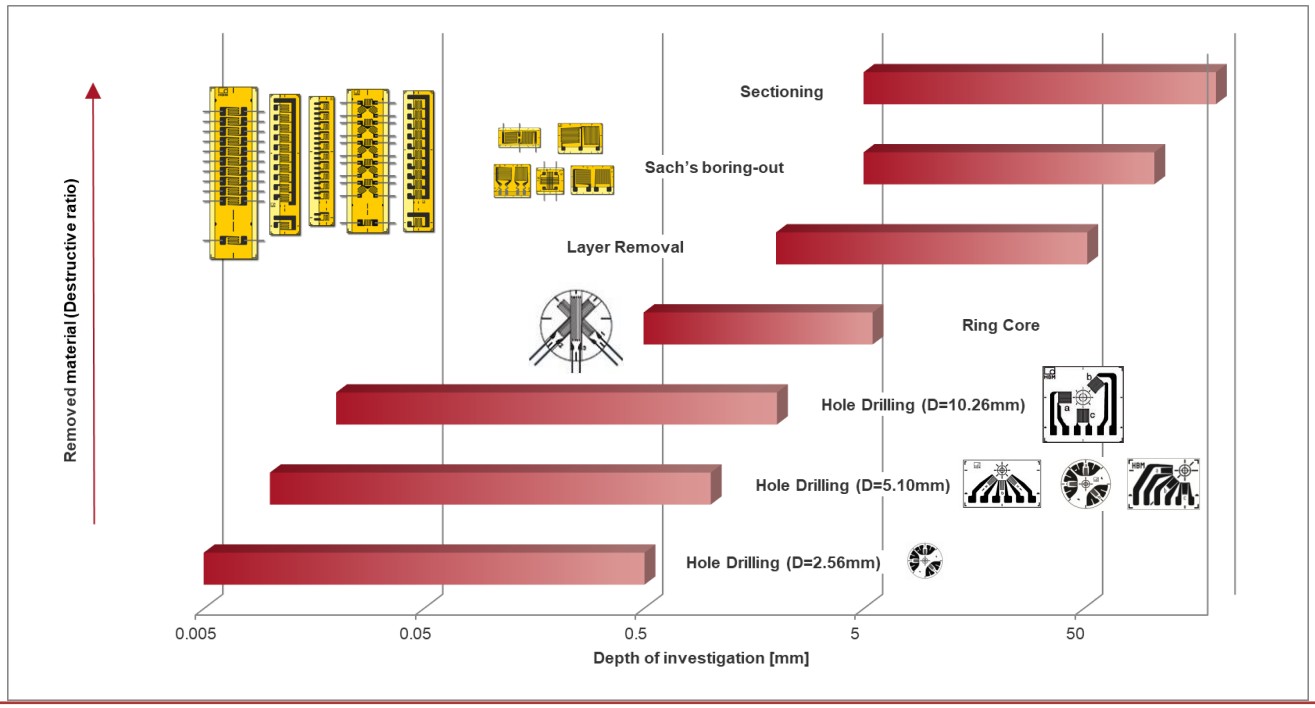
The strain data acquired by the strain gage sensor are used for the back calculation of residual stresses using special influence functions.

The strain gage residual stress methods are commonly divided in 2 families:

- Semi destructive methods (Hole drilling method, Ring Core method)
- Destructive methods (Layer removal, Sach's and Sectioning methods)

The semi-destructive methods remove just a small quantity of material closer to a strain gage rosette placed in the measurement area, leaving its overall structural integrity intact for other testing or use. This is why these methods (mainly the hole drilling method) are considered semi-destructive. On the contrary, **the destructive methods need a higher remotion of material** (cuts and milling process) that completely destroy the testing workpieces.

Each strain gage residual stress method has a particular depth of analysis that can offer a wide range of applications:



The hole-drilling method for the measurement of residual stresses

The hole-drilling method allows accurate experimental stress analyses at moderate costs. It consists in drilling a small hole (typically 1.8 – 2.0 mm) which changes the initial deformation allowing redistribution of the residual stresses locked in a material.

The strains that are released in this way can be measured by a specially configured three-element strain gage rosette and then used in special calculation system to determine the residual stresses that exist in a material.

Briefly summarized, the measurement procedure involves the following steps:

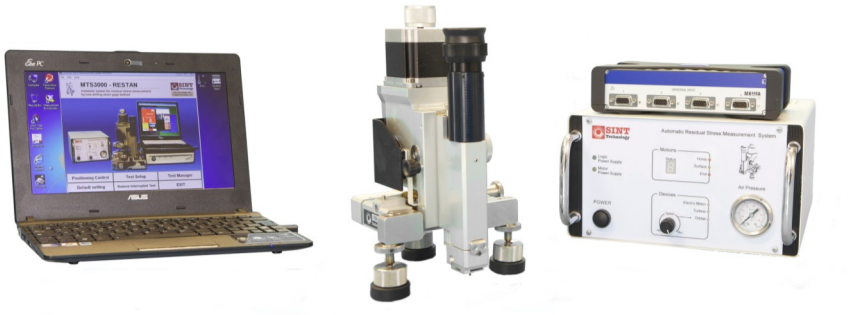
- A strain gage rosette with three radial grids is installed
- A through hole or a blind hole is drilled through the geometric centre of the rosette
- Readings are made of the strains produced by relieving the residual stresses
- The residual stresses are calculated from the measured strains using special calculation algorithms

The hole drilling residual stress method is regulated by the ASTM E837-13a standard applicable to uniform or not uniform residual stress field in the depth.

With the strength of many years of experience in the field of strain gage measurements, mechanical design engineering and software development, **SINT Technology has developed and patented a fully automated system for measuring residual stresses.**

SINT Technology uses its own system, the MTS3000, also known as RESTAN (Residual Stress Analyzer), which allows residual stresses to be measured by the hole-drilling method and the data acquired by that technique to be processed by five possible calculation systems:

- The ASTM E837-13a Standard Test Method for uniform stresses
- The ASTM E837-13a Standard Test Method for non-uniform stresses
- The Integral Method
- The Schwarz-Kockelmann Method
- HDM method



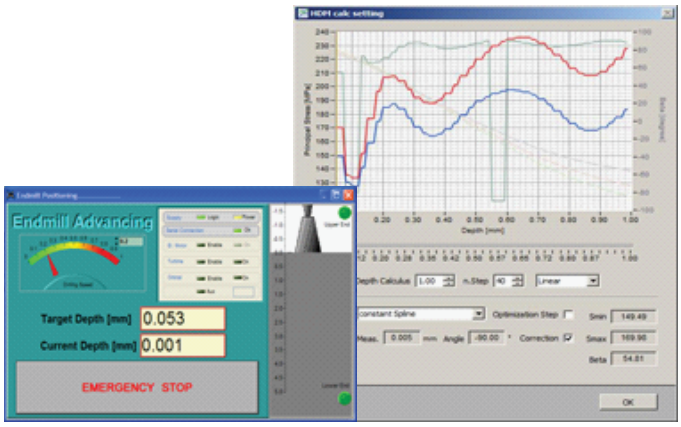
The first method allows the residual stress measurement in the case of uniform distribution. The other 3 methods allow measurement of residual stress variation in the depth.

Consequently, **the system provides a complete analysis of relieved strain distribution and of near-surface residual stress profiles on completion of testing**.

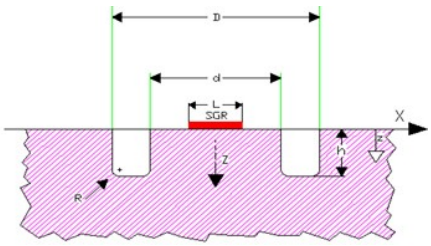
Thus, use of the MTS3000 - Restan technology plus the presence of expert engineers allow the best results to be achieved for the most diverse requirements.

SINT Technology engineers have both experience and expertise in measurement of residual stresses and technical knowledge of the MTS3000 - Restan system, being directly involved in managing the quality of the product and in the setting, calibration and inspection and testing processes.

For this kind of tests, SINT Technology is also a ISO/IEC 17025 accredited laboratory.



The Ring Core method for the measurement of residual stresses



The strain gage Ring Core method consists in drilling an annular groove around a special strain gage rosette with three overlapped grids.

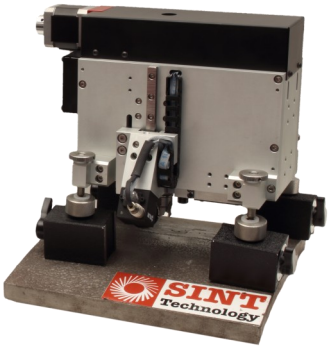
The dimension of the core is about 18mm x 14mm (external and internal diameter), with a typical depth of 4 to 5 mm.

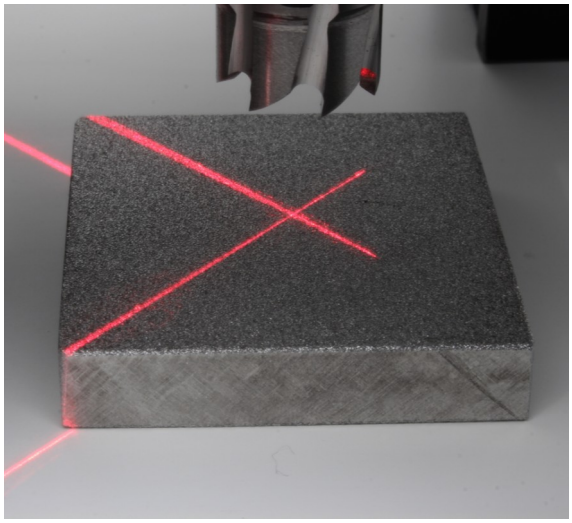
The method allows the calculation of uniform and not uniform residual stress in the depth.

This kind of measurement produces a big strain signal (3-4 times higher than hole drilling for the same residual stress field), lower sensitivity to the eccentricity errors and a greater depth of investigation.

The Ring Core method is used for industrial aims for the determination of residual stresses on large size forged and casted items (shafts, compressors and turbine disks) in which the calculation of residual stress on the surface is less important.

SINT Technology has developed, made and patented an automatic system for the determination of residual stress using the Ring Core method, and offers also a measurement service in laboratory or directly on field.

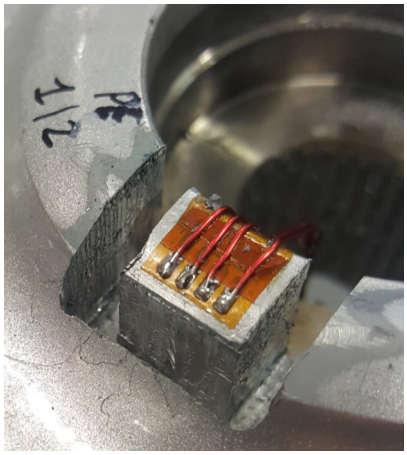


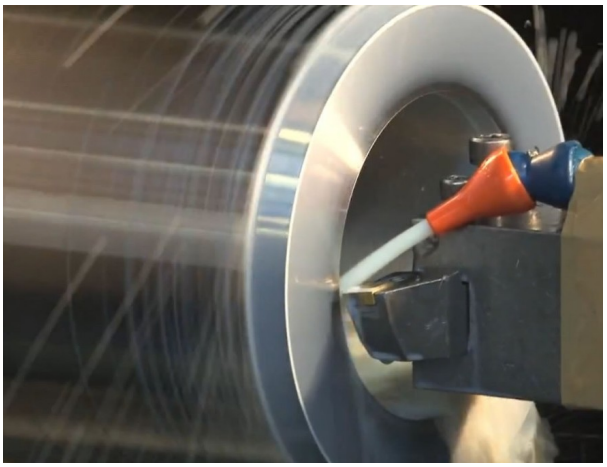


Other strain gage methods for the measurement of residual stresses

SINT Technology offers also custom solutions for analysis of residual stresses with other strain gage methods: for example, Sach's boring-out, layer removal and sectioning.

Sectioning method is used for the determination of residual stresses inside railway workpieces made in steel according to the EN 13674-1.





Training on strain gage and residual stress measurements

SINT Technology offers training about strain gages and residual stress applications both in the laboratory or directly in the companies.

The training courses are divided in theoretical lessons and practical installations of strain gages and measurements with the main residual stress methods.

Accreditation about residual stress measurement

SINT Technology is a ISO/IEC 17025 accredited laboratory which provides residual stress determination by the hole-drilling method, both for laboratory work and field tests.

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LAB N° 0910

Contact us

Via delle Calandre, 63 - 50041 Calenzano (FI) ITALY

Tel: +39.055.8826302

Fax: +39.055.8826303

www.sintechnology.com

info@sintechnology.com

VAT n. 04185870484

Recognitions

SINT Technology's test laboratory is accredited to standard ISO/IEC 17025:2005 by the Italian accreditation body **ACCREDIA with certificate no. 0910**

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Certification of conformity to the requirements of standard

UNI EN ISO 9001