## Definition of residual stress

Residual stresses are mechanical stresses that occur in a body without the influence of external forces or moments and are in thermal equilibrium.

The internal forces and moments associated with these stresses are in equilibrium.

Tensile residual stresses are usually shown with a positive sign, compressive residual stresses with a negative sign.

## Residual stresses in application

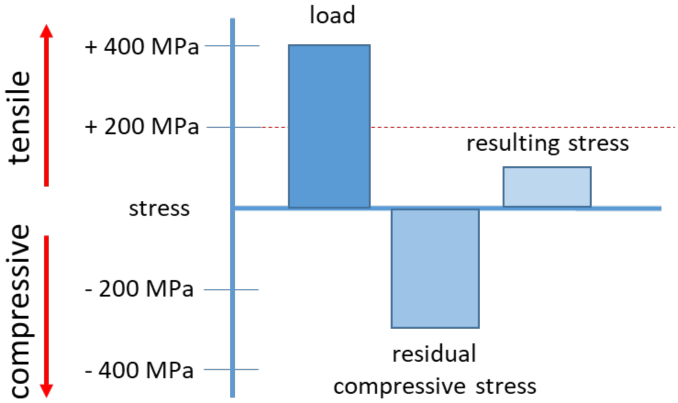


*Illustration 1: Example for residual stresses in application*

- The component is exposed to a load stress (tension) of + 400 MPa in its application
- In terms of construction the component (to achieve a certain lifetime) should experience a maximum of +200 MPa
- Reduction of the maximum load due to compressive residual stresses of – 300 MPa

➔ Total stress is reduced to + 100 MPa

## Occurrence of residual stresses due to the shot peening process and measuring principle

Due to the accelerated abrasive, a force acts on the crystal lattice and compresses it. This reduces the atomic distance $D_0$ to $D$ and creates compressive stresses at the atomic level.

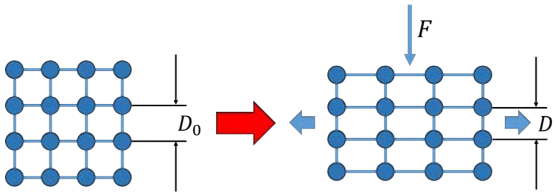


*Illustration 2: Relaxed lattice structure and lattice structure under load*

Compressive residual stresses counteract a tensile load on the component.

By changing the lattice distance, the diffraction angle of the X-rays changes, from which the corresponding residual stresses can be calculated.

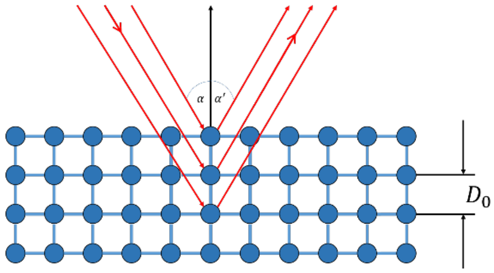


*Illustration 3: Lattice structure of an unblasted surface*

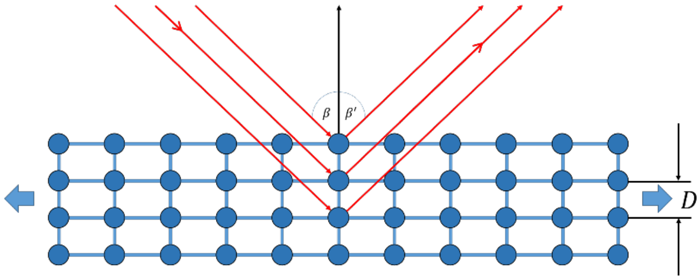


*Illustration 4: Lattice structure of a blasted surface*

## Basic principles of radiographic residual stress measurement:

Residual stresses are direction-dependent. Individual, relevant directions can be measured in a targeted manner by means of X-ray diffraction.

Measurements directly on the component surface can sometimes be carried out completely non-destructively. For a meaningful depth profile of the residual stresses, electrochemical removal and cutting of the specimen is often necessary, making the measurement destructive.

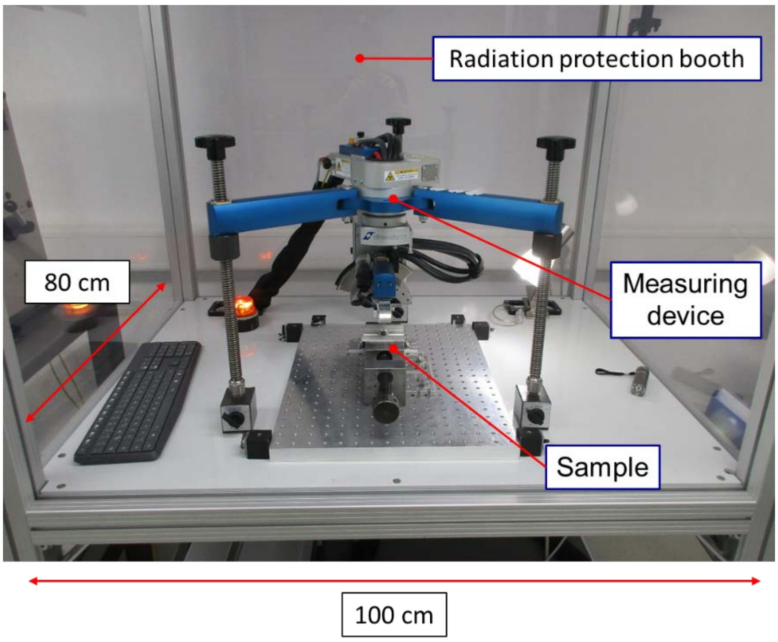


*Illustration 5: Measuring device in radiation protection booth*

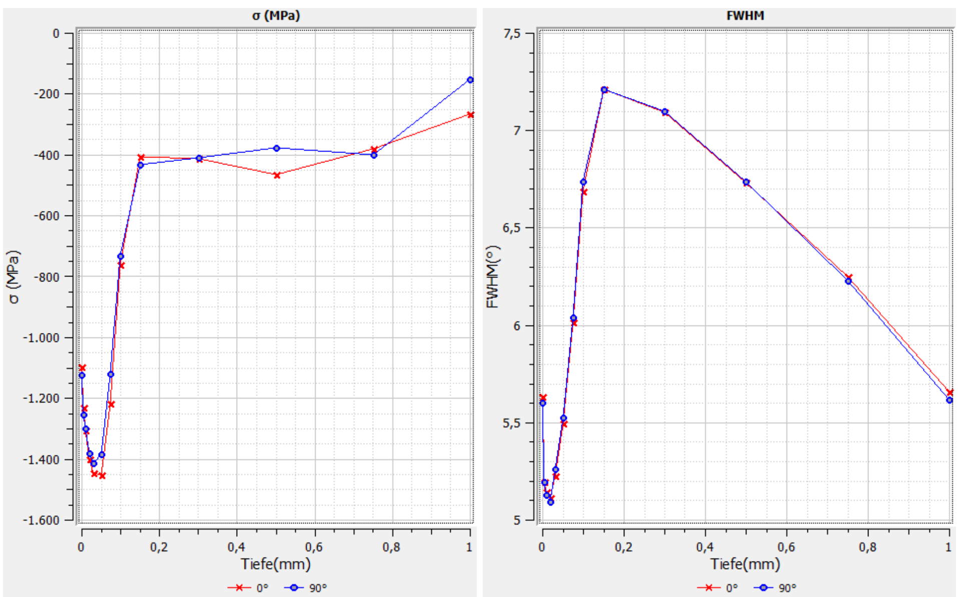


*Illustration 5: Example of depth profile in two different measuring directions (0° and 90°), residual stresses (left) and half-width (right).*

In addition to the residual stresses, the measurements also provide the so-called full width at half maximum (FWHM, Illustration 6 right) as a result. Lattice defects that lead to an increase in material-strength (dislocations, foreign atoms, grain boundaries, ...) also lead to a broadening of the X-ray peak and thus to a higher half-width. The half- width is thus an indirect measure of the material-strength profile. However, it cannot be transferred 1 to 1 to common hardness scales such as HV and HB.

The result of the residual stress measurement forms an average value for the total exposed area. This area depends on the aperture (=collimator) used:

A large aperture:

+ short measuring time (cheaper)

+ Coarse grain structure/grain orientation can be compensated well

- Only to be used on relatively flat surfaces

A small aperture:

+ very local measurements possible

+ Curved surfaces and radii can also be measured

- Coarse grain structure and grain orientation can lead to problems

- long measuring time (partly considerably more expensive)

## **Limitations of the measurement method:**

In order to obtain good measurement results and to be able to carry out a meaningful measurement at all, there are some limitations that should be taken into account:

- Measurability of the material with the appropriate wavelength

-> Possible with OSK-Kiefer: virtually all steels and ferrous materials (ferrite and austenite), aluminum. Nickel with restrictions.

- Accessibility of the measuring point

- Component size is limited by the diameter of the radiation protection booth, measuring device height and measuring position

-> if necessary, the component must be separated

- Radius at measuring point (r * 0.4 must be larger than the orifice diameter). The smallest aperture has a diameter of 0.5 mm

-> if necessary, the measuring point must be moved

Most specimens must be separated to create a depth profile and/or to make the measuring point accessible. For this purpose, suitable cooling is used to prevent heating of the specimen and thus undesirable degradation of the residual stresses.

We are certified according to ISO 9100:2018 as well as ISO 9001:2015 as an X-ray laboratory for residual stress measurement. You can find the current versions of the certificates under:

www.osk-kiefer.de/wp-content/uploads/Zertifikat-EN-9100_2018.pdf

www.osk-kiefer.de/wp-content/uploads/Zertifikat-ISO-9001_2015__DE042021.pdf

**If you have any questions about residual stress measurement or would like a non-binding quote for a measurement, please contact us directly:**

**Mr. Thomas Schiess**
M.Sc. Materials Science and Engineering

Phone: 08137/9316-24

Email: Thomas.Schiess@osk-kiefer.com