



RESIDUAL STRESS IN 3D PRINTED PARTS

Wietech 3D printers empower you to minimize cost and improve manufacturing processes. Offering an open-source platform and easy to operate no special facility requirements, eliminating additional facility expenses. They are suitable for various environments such as classrooms, offices, or shop floors. These user-friendly 3D printers assist you to optimize your conceptual designs, multiple prototype iteration, validate functionality, jigs, fixtures, and manufacturing aids and more, enabling you to enhance production processes and elevate your business to a new level.



Residual Stress in 3D-Printed Steel

Although additive manufacturing (AM) isn't a new process, it's a constantly evolving one. Since its inception, additive manufacturing has helped manufacturers achieve better process flexibility and efficiency, as well as create cost-effective prototypes. Despite the many benefits of additive manufacturing, there are still some critical challenges that need to be overcome, including controlling and reducing residual stress in AM components.

What Causes Residual Stress in Additive Manufacturing?

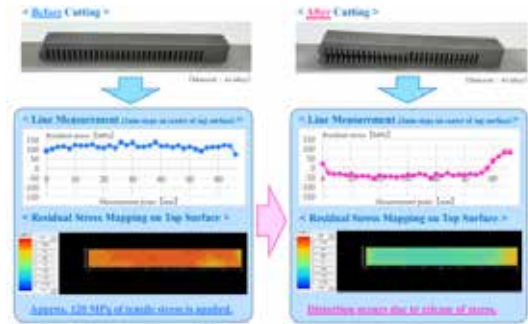
Residual stress in 3D-printed steel and other AM-produced parts is primarily caused by their thermal cycle during the rapid heating and solidification process.

According to the Journal of Manufacturing and Materials Processing, the primary factors contributing to residual stress include the maximum temperature difference, deposit height, substrate stiffness, energy density, and part geometry.

The maximum temperature difference refers to the temperature of the AM bar and the base bar during thermal cycling and, depending on this delta, affects the residual stress within the AM part. If the entire substance is preheated before AM, the maximum temperature gradient (MTG) may be reduced, impacting the stresses within the object. If temperatures are too high, microstructural coarsening can lead to poor mechanical properties.

Scan patterns can also affect residual stress within additive manufacturing produced parts, with Island scan patterns resulting in lower stress levels than alternative scan patterns. Additionally, a Residual Stress Development, Prevention, and Compensation Study published in 2020 found that energy input affects residual stress formations, with slower scanning speeds resulting in more residual stress.

The Effects of Residual Stress in 3D-Printed Components



Additive manufacturing allows the production of complex, varying geometries much quicker than traditional methods, but what effects do residual stresses have on these components?

Researchers who conducted a study on Residual Stress Development in Metal Additive Manufacturing found that the types of stresses found at the very center of AM-produced parts are typically compressive stresses, while the top layers of AM parts typically feature tensile stresses.

Compressive stresses, due to forces pushing in on an object, are beneficial for AM parts and make them stronger and more durable over time. Tensile stresses, on the other hand, can affect a part's fatigue life and properties, increasing its chances of cracking, deformation, and total failure.

Identifying & Measuring Residual Stress

Even though there are a variety of ways to identify and measure residual stress in 3D-printed steel and within AM parts and components, some methods are more ideal than others depending on the use case and type of part being examined. If you'd like to learn more about some of the destructive and non-destructive methods used to measure residual stress, read our Residual Stress Measurement Guide.

Out of all the various measurement methods available, X-ray diffraction (XRD) is one of the best ways to identify and measure these stresses safely and consistently. X-ray diffraction is a fast, safe, and non-destructive method, so you won't have to worry about damaging your component during the measurement process.

XRD analyzers work by using a zero-, one-, or two-dimensional sensor to measure either part or all of the Debye-Scherrer ring, allowing the observation of peak

profiles within certain sections of the ring. Using Bragg's Law, strain can be calculated from the ring's positions.

Can Residual Stress Be Prevented in AM Parts?

While it is difficult to prevent residual stresses in AM parts completely, there are several methods that could be used to reduce the amount of stress present within the solidified and cooled object.

In the Journal of Manufacturing and Materials Processing, a study was published in 2021 by Xufei Lu, Miguel Cervera, Michele Chiumenti, and Xin Lin. This study mentions that some of the best stress control methods include:

- Preheating the substrate or material before the AM process
- Laser or shot peening
- Reducing the maximum temperature gradient
- Heat treatments

Researchers Kevin Carpenter and Ali Tabei also suggested in their 2020 study that AM stresses could be prevented by:

- Lowering heat inputs
- Decreasing laser height and laser power
- Modifying and adjusting scanning speeds and laser power, optimizing for higher scan speeds, and lowering laser power values to reduce residual stresses

Due to the large variety of additive manufacturing techniques available, techniques and strategies to lower residual stresses will vary. This continues to be a widely researched topic, and more studies will need to be completed on residual stress prevention to find the optimum methods for each particular AM use case.



Learn More About Measuring Residual Stress in 3D-Printed Steel & AM Components

Pulstec is an electronic equipment manufacturer that has developed a wide range of innovative products, including the XRD analyzer which can measure both residual stress and retained austenite amounts in polycrystalline material. Our non-destructive XRD analyzer is incredibly fast (results within 60 seconds), lightweight, and uses a two-dimensional sensor to display the full Debye-Scherrer ring. You can learn more about how our analyzer works here.

If you have questions about measuring residual stress in 3D-printed steel and AM components, or you would like to request a free demo of our analyzer, please contact us today.



Toshikazu Suzuki's Bio

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PULSTEC
Pulstec Industrial Co., Ltd.

μ-X360s

Portable X-ray Residual Stress Analyzer

Equipment capable of measuring residual stress, half width height (FWHM), and retained austenite (optional).

Ideal for field measurement. Industrial heat treatment of products, Additive Manufactured produced parts, welding plastic forming, surface reforming, monitoring and maintenance of the factory and infrastructure. Able to measure pipes with internal diameters from 170 mm.

Operability

Easy sample setting, measurement time: Approx. 60 secs (Ferritic samples)

Portability

Sensor unit: Approx. 2.4kg, Power supply unit: Approx. 6.2kg. Ideally suited for field measurements.

Applications

Thermal treatment industrial of products, welding, plastic forming, surface reformation, monitoring and maintenance of plant and infrastructure.

The world's lightest and smallest



Quick and easy setup Simple non-destructive measurements

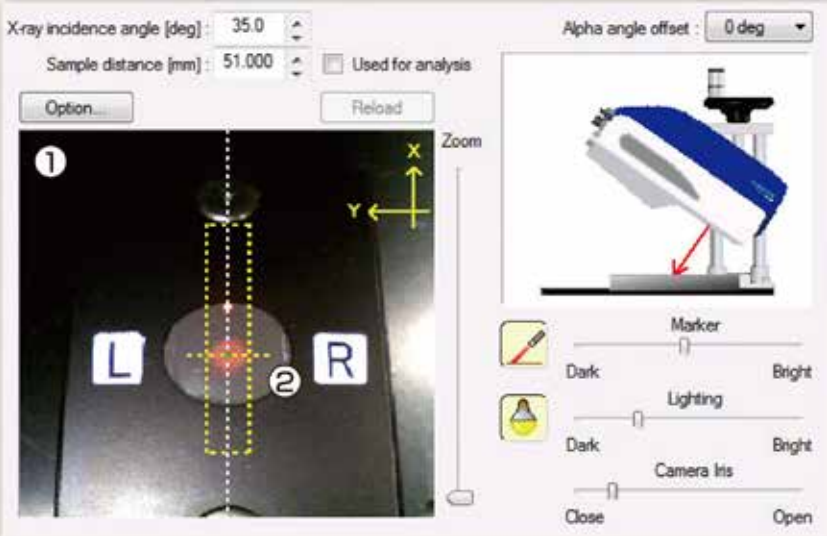
Able to measure in pipes with internal diameters down to 170mm wide.



STEP 1

Sample setting (XYZ adjustment)

Easy sample positioning with integrated LED marker and CCD camera.



① CCD camera image to confirm the correct measurement position

② Yellow dotted line indicates the measurement height range and LED marker shows the X-ray exposure location.

STEP 2

Measurement start

(X-ray exposure
Data analysis)

INDOOR

Laboratory or workshop use

- Interlocked safety cabinet protects users from radiation leakage.
- Easy sample setting using the sensor unit's stand adjustment.



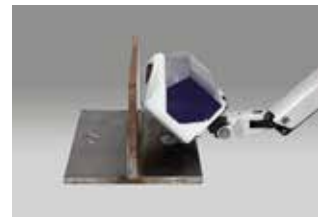
Springs



Crankshafts



Gears



Fillet welds, including HAZ and bead regions

OUTDOOR

Field use

- Non-destructive measurement for larger samples without cutting.
- A single hand-carry case contains all the system, including the sensor and power supply unit, having a total weight of approx. 8.6kg.
- Compact portable batteries for environments where an electrical supply is not available.
- Various directional access to the measurement point with a flexible arm.



Storage tanks: Weld and annealing effects



Rolls: Forming and thermal treatment effects

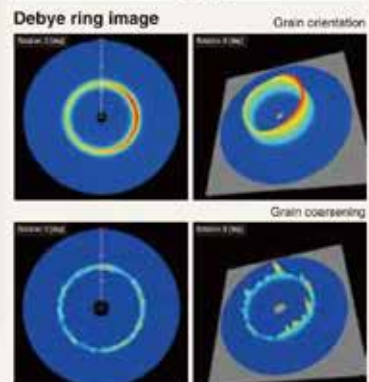
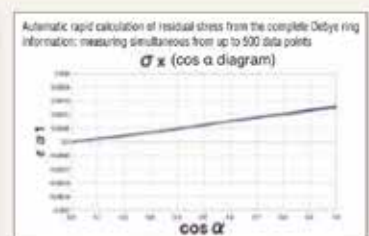
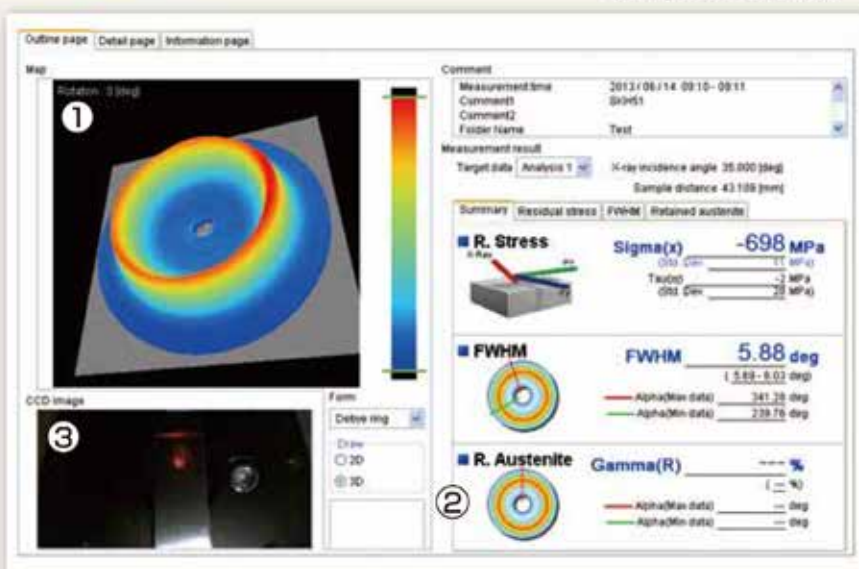


Bridges: Monitoring aging effects

STEP 3

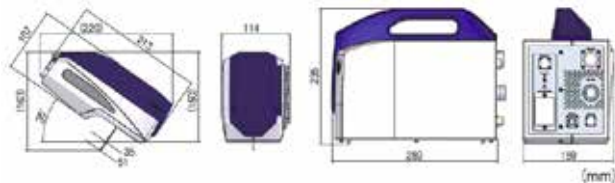
Results displayed

Debye ring data reveals the grain orientation (texture) and grain size, etc.



- ① Debye ring image
- ② Residual stress, FWHM, Retained austenite results.
- ③ CCD camera image for quick and easy sample positioning.

Size • Weight



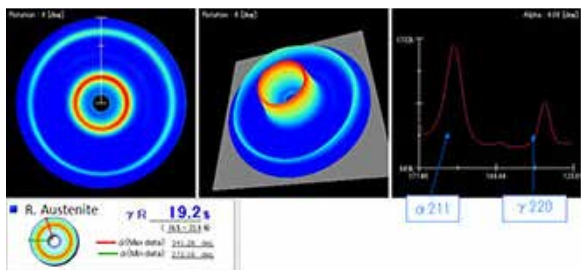
Sensor Unit
Weight: Approx. 2.4kg

Power Supply Unit
Weight : Approx. 6.2k

Specification

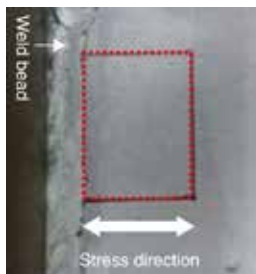
Measurement items	G) Residual Stress @FWHM @Retained austenite (Optional)
Measurement method	Single incident angle X-ray exposure (cosa) method
Collimator size	Standard: c/11.0mm (illumination area at surface Approx.c/2.0mm)
X-ray tube cooling method	Air cooling
Power supply	AC 100-240V, 50/60Hz, 130W

Options



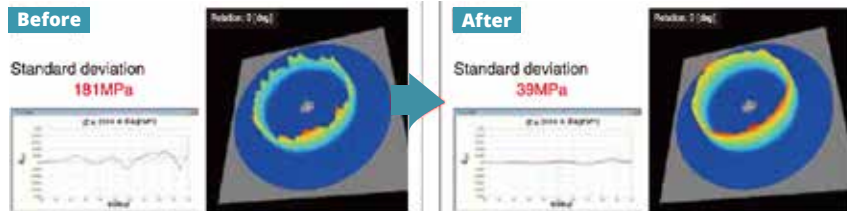
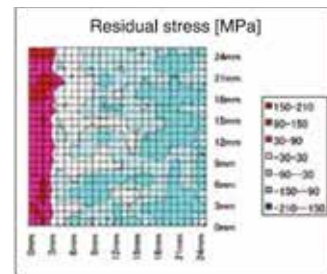
• Retained austenite

Measures the percentage of retained austenite not transformed to martensite upon quenching.



• Mapping function

Stress mapping using software controlled XY axis stage for automatic positioning and measurement.



• Oscillation unit

Measurement accuracy improved by controlled sensor unit oscillation; the changing angles of X-ray exposure allows a greater number of crystal planes to be sampled.



• X-ray tube exchange

Easy X-ray tube exchange by user: enables a greater range of materials to be measured - tube target's available include Cr, V, Cu, Co, Mn

Accessories



Flexible arm



Hand-carry case



Safety cabinet



Electrochemical polisher

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