AutoMATE II

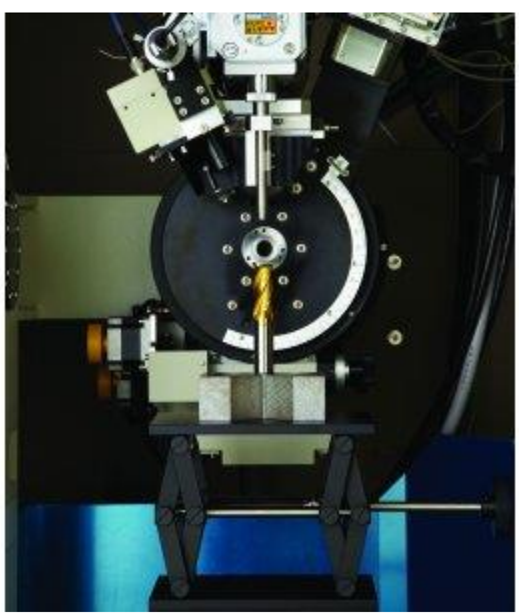
Residual stress may be created during the manufacturing process of a material, or it may accumulate in a structure over many years in operation. In either case, this stress can have a serious negative effect on a product's quality, durability and lifetime. Accurate detection of residual stress is an important element of the quality control process and helps predict the service lifetime of products.

In the past, if you wanted to make highly accurate residual stress measurements, you had to use an R&D diffractometer because of the accuracy of the goniometer. However this restricts the weight and size of the samples you can measure. On the other hand, dedicated laboratory and factory-floor residual stress analyzers suffer from reduced accuracy due to the nature of their mechanical designs, while, in their favor, they have the flexibility of measuring large and heavy parts.

With the AutoMATE II, you now have the best of both worlds. Large and heavy parts (30 kg with standard manual Z stage; 20 kg with optional automated XYZ stage) can be measured with high accuracy.

The X-ray source and detector arm are mounted on a highly accurate two-axis goniometer that can position them relative to the measurement site and perform scans with minimum steps of 0.1 microns when using the automated XYZ stage.

The most advanced new feature of the AutoMATE II lies in an innovative new X-ray detector. The detector used in the AutoMATE II is the D/teX Ultra1000, an electronic Si strip detector that has high dynamic range, high sensitivity, and good energy resolution, as well as not requiring any consumable gas.



Features

- Highly accurate goniometer allows for true micro-area residual stress measurement.
- Automatic mapping measurements with teaching function.
- Large and heavy samples are measured with high accuracy.
- An X-ray radiation enclosure with interlock system automatically locks the enclosure door when the X-ray shutter is open.
- The measurement position is adjusted by a CCD camera equipped with a microscope having a zoom function.
- The two-axis goniometer system allows for both iso-inclination and side-inclination methods automatically without readjustment of the sample position.

- **Table 1. Specifications of Automate II**

X-ray generator	Maximum power	3 kW (Tube voltage 20 - 50 kV, Tube current 2 - 50 mA)
	Stability	±0.03 % (Power fluctuation within ±10%)
	X-ray tube	Standard: Cr (Maximum load 2 kW), Effective focus size 1 × 10 mm2 (N.F.), Short type Option: Cu (2 kW), Co (1.8 kW), Fe (1.5 kW), V (0.3 kW)
Goniometer	2θ scanning range	2θ = 98° to 168° (Central angle range of D/teX Ultra 1000 2θc = 108° to 158°)
	ψ angle range	ψ = 0° to +60° (at maximum)
	Oscillation range	ψp = ±1° to ±10°

	Incident collimator	Standard: φ150 μm, φ1 mm Option: φ30 μm, φ50 μm, φ100 μm, φ300 μm, φ500 μm, φ2 mm, φ4 mm
	Distance	X-ray source - sample: 265 mm Sample - detector: 210 mm
Sample stage	Standard: Manual Z stage	Lab. jack (Model LJA-16223) Maximum sample space: 720 mm (W) × 560 mm (D) × 540 mm (H) Stage dimensions: 160 mm × 220 mm Maximum load: 30 kg
	Option: Auto XYZ stage	Maximum sample space: 720 mm (W) × 560 mm (D) × 335 mm (H) Stroke: X-Y axis = ±50 mm, Z axis = -5 mm to + 35 mm Stage dimensions: 150 mm × 150 mm Maximum load: 20 kg
X-ray shutter		Rotary shutter
Sample alignment system	CCD camera	Magnification: ×22 to ×135 (Field of vision 6 mm to 1 mm) Focal distance: 90 mm
Detector (D/teX Ultra 1000)	Dimension	One dimension (Semiconductor system)
	Number of channels	1024 ch

	Maximum counting rate	1 × 106 cps/ch × 1024 ch (Total 1 Gcps/all)
	2θ angle resolution	0.02° (Strip width 75 μm/line)
	Window area	76.8 mm × 10 mm
	Size, Weight	135 mm (W) × 95 mm (D) × 100 mm (H), 1.4 kg
	Kβ filter	Standard: V (Cr)Option: Ni (Cu), Fe (Co), Mn (Fe), Ti (V)

- **Table II. Specifications of software**

Software	Residual stress (Measurement)	sin2ψ method Iso-inclination method, Side-inclination method ψ0-fixed method X-Y teaching function
	Residual stress (Data processing)	Batch processing of multiple data Smoothing Background elimination LPA correction Kα1, Kα2 separation Peak search (FWHM center method, Parabolic approximation method, Center of gravity method, FW2/3M center method, FW2/5M center method)

	Retained austenite (Measurement)	α-Fe(211): 2θ = 156.40° (Cr Kα), γ-Fe(220): 2θ = 128.83° (Cr Kα) X-Y teaching function
	Retained austenite (Data processing)	Batch processing of multiple data Normalization factor of diffraction intensity: R = 0.36746 (or user setting value)

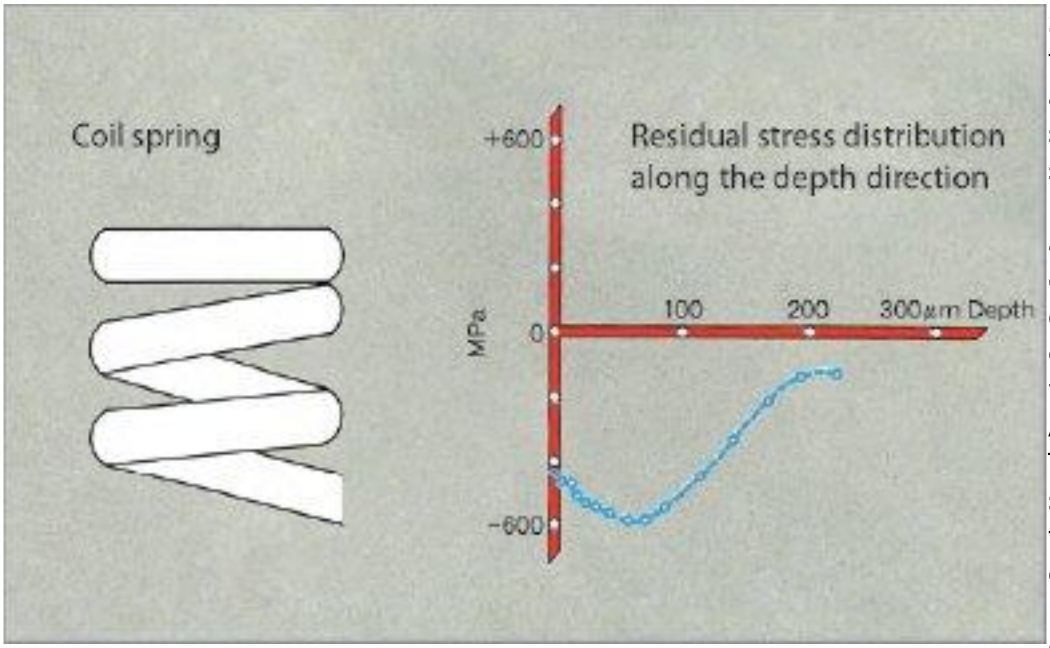
- **Table III. Specifications of utilities**

Cooling water system (TCA2KCN-D)	Cooling system	Air-cooled water chiller
	Cooling capacity	2 kW
	Cooling temperature range	15°C to 25°C
Computer	PC	Desktop personal computer
	OS	Windows® 7 Professional (32 bit)
	Display	19" TFT
	Printer	Ink jet color printer

	Computer rack	Vertical type

Application:

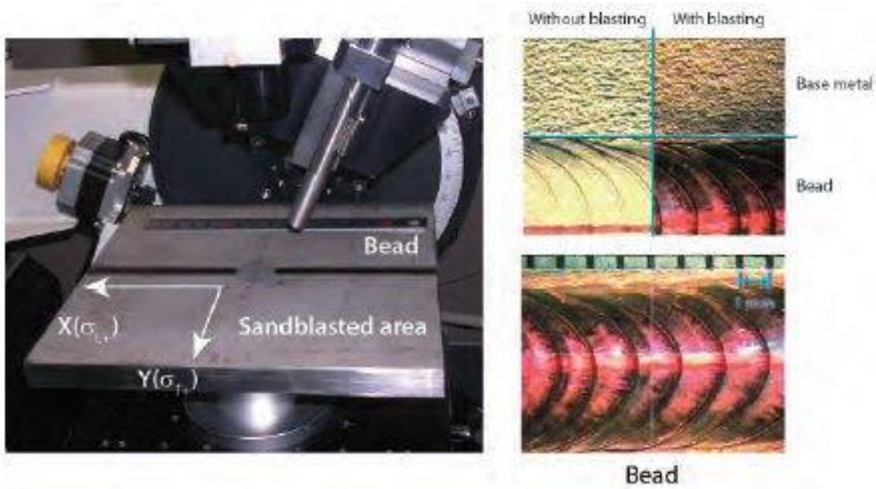
Evaluation of the effects of shot-peening treatment on the surface of a spring by X-ray stress measurement

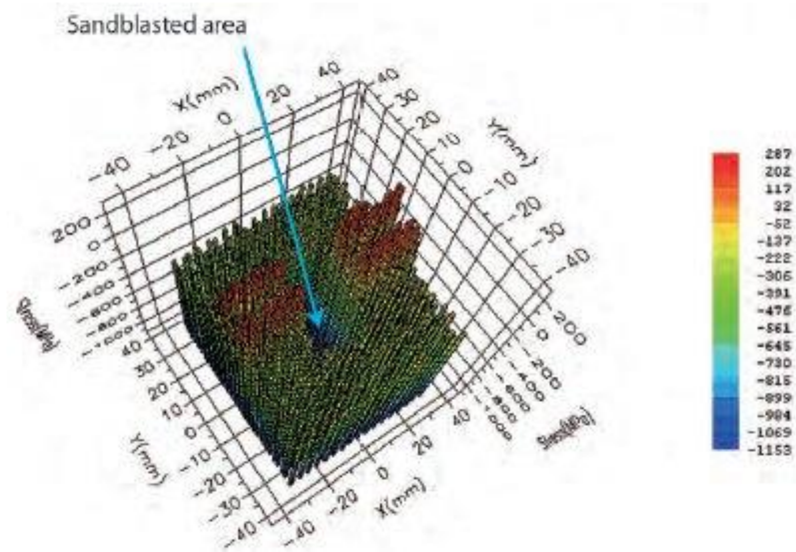


Shot-peening treatment is applied to the spring surface. The residual stress along the depth direction is evaluated with AutoMATE II. The figure shows that the compressive residual stress on the sample surface is equivalent to -410 MPa and the maximum compressive residual stress, at the depth of 60 microns from the sample surface, is equivalent to -600 MPa. It also shows that in the deeper areas than 60 microns from the surface the compressive residual stress is getting smaller and smaller along the depth direction, indicating the typical stress state for the shot-peening.

Mapping measurement of the weld bead on a SUS304 plate

On the weld bead, the residual stress is approximately equal to zero. Tensile stresses from 200 MPa to 300 MPa are observed in the heat-treated area in the base metal. In the sandblasted area, the mapping chart shows that the tensile stress has changed to the compressive stress of about -1000 MPa by the sandblast treatment. By using the CCD camera with a zoom function, the images of the sandblasted and non-sandblasted areas are recorded as shown in the pictures.


Without blasting
With blasting
Base metal
Bead
Bead
X(σ_{L})
Sandblasted area
Y(σ_{T})
Bead


Sandblasted area
X(mm)
Y(mm)
Stress(MPa)
287
202
117
32
-52
-137
-222
-306
-391
-476
-561
-645
-730
-815
-899
-984
-1069
-1153