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AutoMATE II

Micro-area X-ray stress measurement system

Highly accurate micro area residual stress

Rigaku

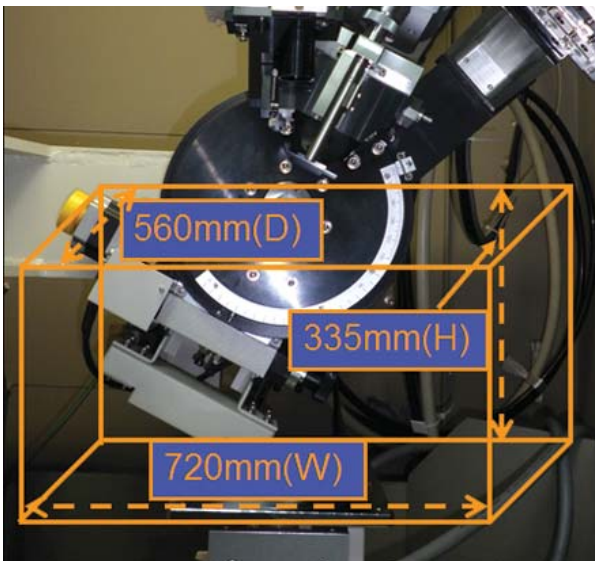
Leading With Innovation

The accuracy of an R&D diffractom
dedicated residua

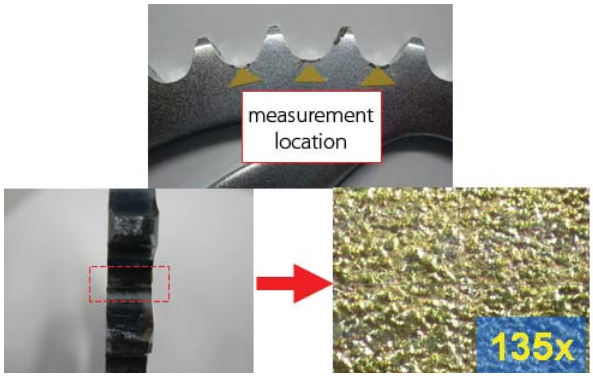
In the past, if you wanted to make highly accurate residual stress measurements, you had to use an R&D diffractometer because of the accuracy of the goniometer. However this restricts the weight and size of the samples you can measure. On the other hand, dedicated laboratory and factory-floor residual 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. This is possible because 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 an accuracy of 0.1 microns when using the automated XYZ stage.

Large and heavy samples are measured with high accuracy by utilizing a 2-axis goniometer with a stationary sample stage. The working volume for a sample is 720 mm (W) × 560 mm (D) × 540 mm (H) and the maximum sample weight is 30 kg. An optional sample stage can hold 20 kg and is equipped with an automatic XYZ stage with X, Y translations of -50 ≤ X, Y ≤ 50 mm and a Z translation of -5 ≤ Z ≤ 35 mm. The working volume for a sample with the automated XYZ stage is 720 mm (W) × 560 mm (D) × 335 mm (H). Some testing devices, including a 4-point bending device, can be attached to the sample stage.



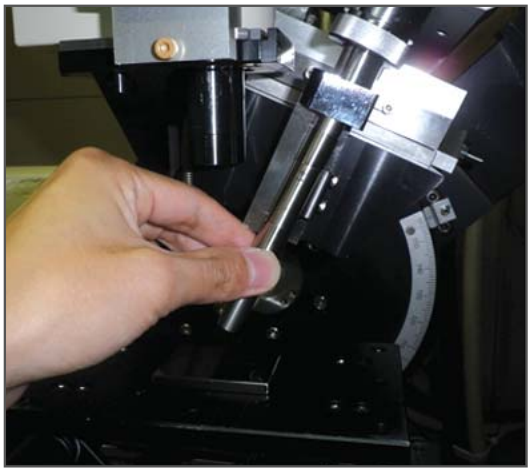
A useful and powerful feature that is typically found on high-end diffractometers is a video system for aid in measurement position selection, as well as being used to provide a permanent record of which area of the sample was analyzed. This is invaluable for record keeping, and can easily be incorporated into a corporate LIMS system for future reference.



A CCD camera equipped with a microscope with a zoom function is used to select the measurement position (Magnification : 22x to 135x). By using the computer controlled XYZ sample stage, a measurement position can be selected remotely and the image of the measurement position can be recorded. The image to the left shows the bottom of a gear between two teeth.

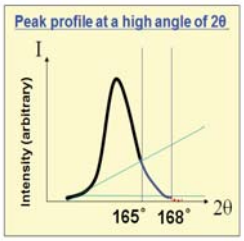
eter with the sample flexibility of a l stress instrument

Just like a high-end diffractometer, the AutoMATE II is equipped with a series of collimators that allow you to adjust the size of beam that is hitting the surface of your sample. Micro stress analysis requires small collimators, and these can only be successfully used when the accuracy of the goniometer is smaller than the diameter of the X-ray beam. AutoMATE II gives you the ability to measure micro areas on large, heavy samples.



Residual stress in a micro area is measured by utilizing optional collimators. The collimators are easy to install and remove. Optional sizes are: φ30 µm, φ50 µm, φ100 µm, as well as φ300 µm, φ500 µm, φ2 mm, and φ4 mm. Standard collimator sizes are φ150 µm and φ1 mm.

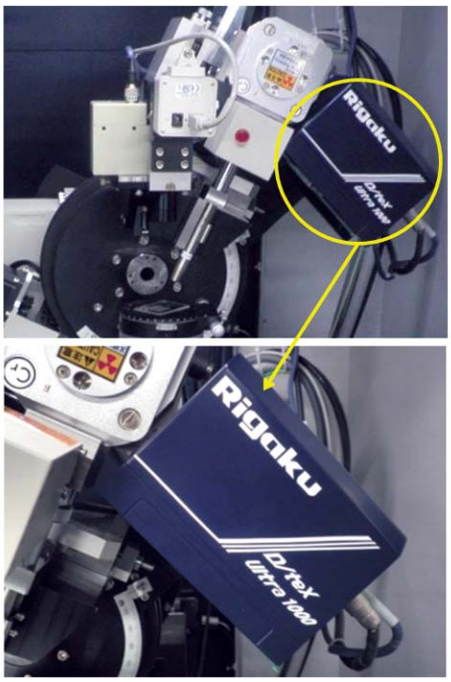
It is sometimes beneficial to accurately determine the background when peaks are broadened due to specific treatments. The AutoMATE II provides this capability by offering a wider 2θ range (20°) compared to some dedicated residual stress instruments.



A wide angular range of 2θ from 98° to 168° is provided in order to accurately determine the background of the observed peak profiles with the broadened FWHM for the residual stress measurements of shot-peened or quenched materials.

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.

The sensitivity of the D/teX Ultra1000 is 1.7 times higher than the previous detector. The dynamic range is 1024 x 10^6 cps for the whole detector. The large dynamic range allows the new AutoMATE II to measure samples consisting of coarse grains without having to reduce the power of the generator. The energy resolution is 36% for Cr *Kα* and 19% for Cu *Kα*, respectively. This advantage allows you to improve your signal to noise by reducing the fluorescence that increases background.



The AutoMATE I
dedicated laboratory stre

Unique advantage #1
Mapping

Automatic mapping measurements can be defined using a "teaching" function. Multiple parts can be placed on the same stage platform for higher throughput. Different mapping positions can be programmed for different measurement conditions.

Unique advantage #2
Sample size

Large and heavy samples are measured with high accuracy by utilizing a goniometer that moves around a stationary sample stage.

Unique advantage #3
Interlocked enclosure

An X-ray radiation enclosure with interlock system automatically locks the enclosure door when the X-ray shutter is open for maximum safety.

Unique advantage #4
CCD camera

The measurement position is adjusted by a CCD camera equipped with a microscope having a zoom function. (Magnification: 22x to 135x).

l is the ultimate
ess measurement system

Unique advantage #5
Micro area measurement

Residual stress in a small area is measured by utilizing the optional collimators. These collimators are easy to switch and do not require realignment. Optional sizes are: φ30 µm, φ50 µm, φ100 µm, as well as φ300 µm, φ500 µm, φ2 mm, φ4 mm. Standard collimator sizes are φ150 µm and φ1 mm.

Unique advantage #6
iso- and side-inclination

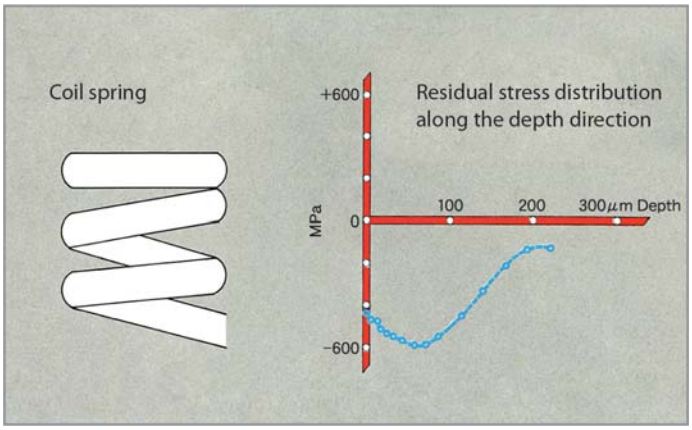
The highly accurate two-axis goniometer system allows for both iso-inclination and side-inclination methods automatically without readjustment of the sample position.

Unique advantage #7
High diffraction angle

Wide angular range (2θ from 98° to 168°) is provided in order to accurately determine the background of the observed peak profiles with the broadened FWHM for the residual stress measurements of shot-peened or quenched materials (e.g. steel, etc.).

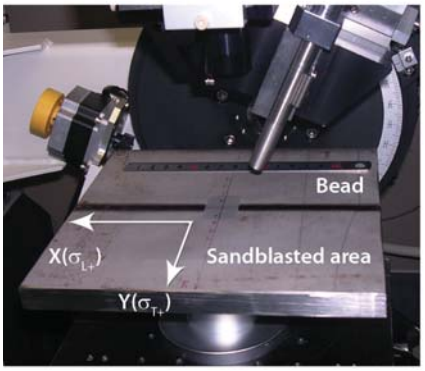
Applications

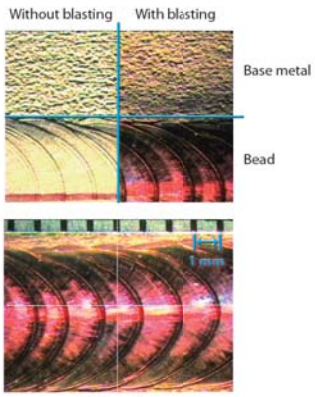
Evaluation of the effects of shot-peening treatment on the surface of a spring by X-ray stress measurement

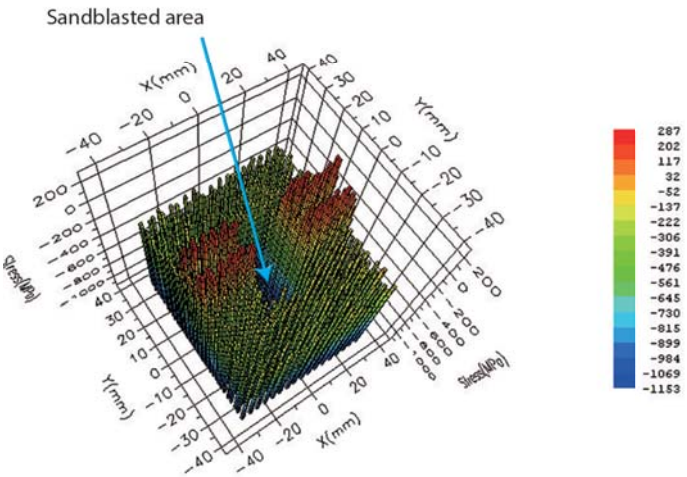


Shot-peening treatment is applied to the spring surface. The residual stress along the depth direction is evaluated with AutoMATE II. The left figure shows that the compressive residual stress on the sample surface is equivalent to -410 MPa and the maximum compressive residual stress, at the depth of 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 left pictures.

Table I. 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 mm^2 (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: $2\theta_c$ = 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 × 10^6 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)	$\sin^2\psi$ method Iso-inclination method, Side-inclination method ψ_0-fixed method X-Y teaching function
	Residual stress (Data processing)	Batch processing of multiple data Smoothing Background elimination LPA correction $K\alpha_1$, $K\alpha_2$ 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 $K\alpha$), γ-Fe(220): 2θ = 128.83° (Cr $K\alpha$) 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 inch TFT
	Printer	Ink jet color printer
	Computer rack	Vertical type

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