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Strain Gauge and Instrumentation for Residual Stress Measurements

A predominant factor contributing to the structural failure of machine parts, pressure vessels, framed structures, etc., may be the residual "locked-in" stresses that exist in the object prior to its being put into service. These residual stresses are usually introduced during manufacturing and are caused by processes such as casting, welding, machining, heat treating, molding, etc.

Residual stress can neither be detected nor evaluated by conventional surface measurement techniques, since the strain sensor (strain gauge, photoelastic coating, etc.) can only respond to strain changes that occur after the sensor is installed.

The most widely used practical technique for measuring residual stresses is the hole-drilling strain gauge method described in ASTM Standard E837. With this method, a specially configured electrical resistance strain gauge rosette is bonded to the surface of the test object and a small shallow hole is drilled through the center of the rosette. The local changes in strain due to introduction of the hole are measured and the

relaxed residual stresses are computed from these measurements. Measurements Group Tech Note TN-503, Measurement of Residual Stresses By The Hole-Drilling Strain Gauge Method, presents a detailed discussion of the theory and application of this technique.

The hole-drilling method is generally considered semi-destructive, since the drilled hole may not noticeably impair the structural integrity of the part being tested. Depending on the type of rosette gauge used, the drilled hole is typically 0.062 or 0.125 in (about 1.5 or 3.0 mm), both in diameter and depth. In many instances, the hole can also be plugged, if necessary, to return the part to service after the residual stresses have been measured.

The practicality and accuracy of this method is directly related to the precision with which the hole is drilled through the center of the strain gauge rosette. The Measurements Group RS-200 optical milling guide described herein provides a practical means to accomplish this task.

Equipment

The RS-200 Milling Guide is a precision fixture for the accurate positioning and drilling of a hole through the center of the strain gauge rosette. Principal features and components of the milling guide assembly are shown in the photos below. When installed on the workpiece, the guide is supported by three leveling screws which are footed with swivel mounting pads to facilitate attachment to uneven surfaces.

Alignment of the milling guide relative to the strain gauge rosette is accomplished by inserting a special-purpose microscope into the guide's centering journal and then positioning the guide precisely over the center of the rosette by means of four X-Y adjusting screws. The microscope assembly, consisting of a polished steel housing with eyepiece, reticle and objective lens, permits alignment to within 0.0015 in (0.038 mm) of the gauge center. The microscope is also used to measure the diameter of the hole after it is drilled. An illuminator attaches to the base of the guide to aid in the optical alignment procedure.

After alignment is achieved, the microscope is removed from the guide and the milling bar inserted in its place for slow-speed drilling of the hole. Two standard milling cutters are supplied: 0.062 and 0.125 in (1.6 and 3.2 mm) diameter. The milling bar is equipped with a universal joint for flexible connection to a drill motor.

Conventional slow-speed milling may be satisfactory on some mild steels and aluminum alloys. But high-speed drilling is generally the most convenient and practical method for introducing the hole in all test materials. (When residual stresses are to be measured on materials such as stainless steels, nickel-based alloys, etc., ultra-high-speed drilling techniques are preferred.) For this purpose, a high-speed air-turbine assembly is supplied for use with the milling guide, along with a supply of tungsten carbide-tipped cutters [ten each 0.031 in (0.8 mm) diameter and 0.062 in (1.6 mm) dia].

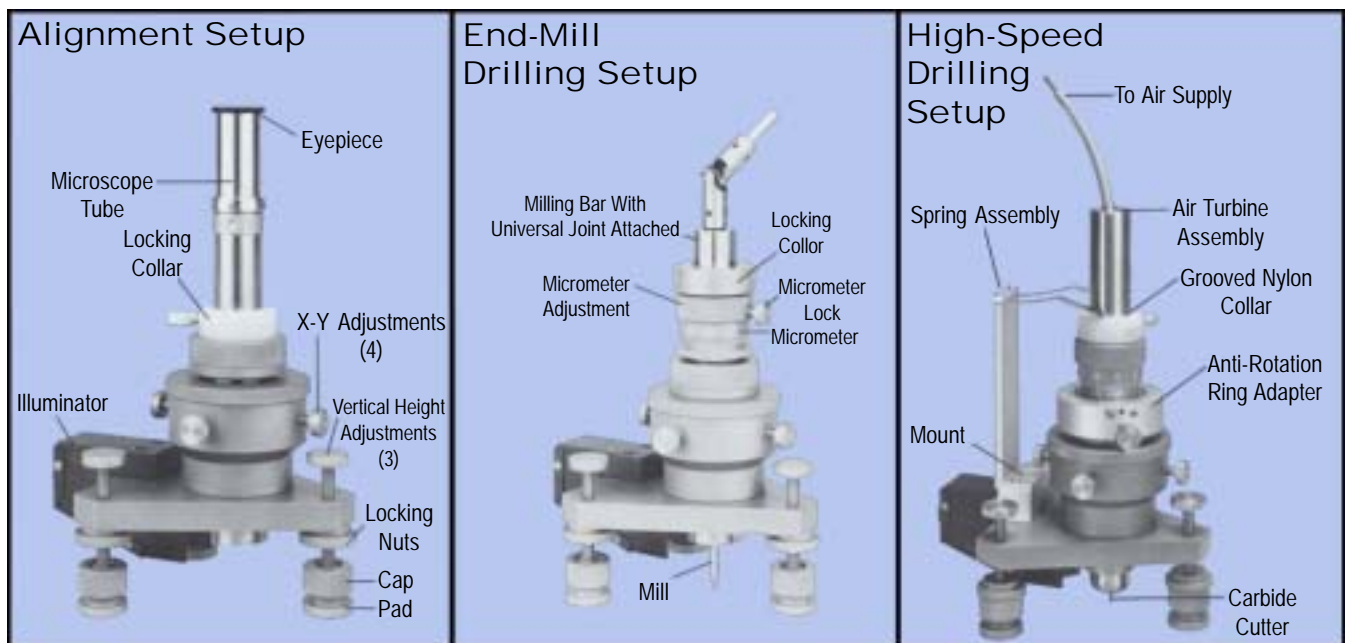


A foot pedal control is included for operating the air turbine.

Also part of the milling guide assembly is a micrometer depth set attachment. This device is used for incremental drilling in those cases when information on the variation of residual-stress-with-depth is considered essential.

Other items supplied include a plastic template for the proper location of the milling guide foot pads on the test part, a fast-setting-cement kit for firmly attaching the guide to the test part and a special break-off tool which is used to remove the foot pads from the part after the test is completed. All components are housed in a sturdy carrying case.

The guide is approximately 9 in (230 mm) high and 4.5 in (114 mm) wide at the base.



Residual Stress Measurement Procedure

Making residual stress measurements with the RS-200 Milling Guide consists of the following steps:

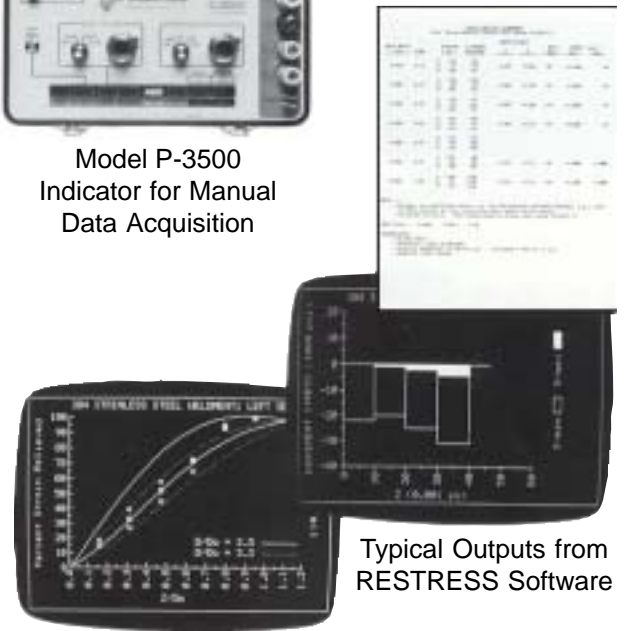
1. A special three-element Micro-Measurements strain gauge rosette is bonded to the test part at points where residual stresses are to be determined.
2. Each rosette grid element is connected to a strain measuring instrument and "zero" readings are recorded.
3. The RS-200 Milling Guide is positioned over the center of the gauge and securely attached to the test part.
4. The RS-200 is optically aligned so that its drilling axis is precisely positioned over the target at the center of the strain gauge rosette.
5. A hole is drilled through the center of the rosette and into the test part.
6. Strain gauge instrumentation is used to obtain strain readings.



7. Residual stresses are then computed, either manually or by using the Measurements Group's RESTRESS software program. RESTRESS is available on either 5-1/4 or 3-1/2 in disks for use with most MD-DOS PC-compatible computers. RESTRESS provides data reduction in accordance with ASTM Standard Method E837, as well as approximate determination of residual stress variation with depth. (Refer to TN-503).



Model P-3500
Indicator for Manual
Data Acquisition



Typical Outputs from
RESTRESS Software

Accessories and Replacement Parts for the RS-200

Listed below are accessory items and replacement parts for the RS-200 Milling Guide.

Double-Ended Boring Mills

Although boring mills are supplied as standard equipment with the basic guide, replacement will be necessary after prolonged usage. These mills, of high-speed steel, are available in two sizes:

HS-200-125, 0.125 in (3.2 mm) diameter.

HS-200-062, 0.062 in (1.6 mm) diameter.

Cutters For High-Speed Air Turbine

Cutters are inverted-cone, carbide-tipped:

ATC-200-062, 0.062 in (1.6 mm) diameter.

ATC-200-031, 0.031 in (0.8 mm) diameter.

Type RM-1 Motor for High-Speed Air Turbine

Cement Kit

A fast-setting (15 minutes) two-component resinous-type dental cement especially suited for firmly attaching the milling guide to the test part. Standard packaging is approximately two ounces. One package is sufficient for ten guide mountings.

A full line of strain gauge instruments for measuring the strain magnitude is also available from the Measurements Group.

Special Rosette Strain Gauges






All gauges are constructed of self-temperature-compensated constantan foil, mounted on a flexible polyimide carrier. Since their application is generally associated with a precision alignment milling guide, each incorporates a centering target. The unique features of each construction are:

EA Series: Normally supplied “open-faced”, but also available with solder dots and encapsulation (Option SE).

TEA Series: Fully encapsulated with easily accessible copper terminals to facilitate installation.

CEA Series: Incorporates all the advantages of Micro-Measurements’ popular ‘C’ Feature gauges. Pattern is specifically designed for applications where it is impractical to use RE or RK configurations (i.e., adjacent to weldments, corners and intersecting surfaces). Care must be exercised when using this pattern, however, as limitations may exist in data reduction equations.

Refer to Micro-Measurements Catalog A-110 for detailed information concerning strain gauge installation accessories. Refer to Catalog 500 for detailed information about rosette specifications.

GAUGE PATTERN AND DESIGNATION <small>Insert Desired S-T-C- No. in Spaces Marked XX.</small>	RES IN OHMS	DIMENSIONS inches millimetres					
		GAUGE LENGTH	GRID CTR LINE DIA.	TYPICAL HOLE DIA.		MATRIX	
				Min.	Max.	Length	Width
EA-XX-031RE-120 EA-XX-031RE-120/Option SE 	120 ±0.2% 120 ±0.4%	0.031	0.101	0.03	0.04	0.29	0.29
		0.79	2.56	0.8	1.0	7.4	7.4
Due to small pattern size, measurement error can be magnified by slight mislocation of drill hole. Pattern not recommended for general-purpose applications.							
EA-XX-062RE-120 EA-XX-062RE-120/Option SE 	120 ±0.2% 120 ±0.4%	0.062	0.202	0.06	0.08	0.42	0.42
		1.57	5.13	1.5	2.0	10.7	10.7
Most widely used RE pattern for general-purpose residual stress measurement applications.							
EA-XX-125RE-120 EA-XX-125RE-120/Option SE 	120 ±0.2% 120 ±0.4%	0.125	0.404	0.12	0.16	0.78	0.78
		3.18	10.26	3.0	4.1	19.8	19.8
Larger version of the 062RE pattern.							
TEA-XX-062RK-120 	120 ±0.4%	0.062	0.202	0.06	0.08	0.60	0.60
		1.57	5.13	1.5	2.0	15.2	15.2
Fully encapsulated, with copper terminals for ease of soldering. Same pattern geometry as 062RE pattern.							
CEA-XX-062UM-120 	120 ±0.4%	0.062	0.202	0.06	0.08	0.38	0.48
		1.57	5.13	1.5	2.0	9.6	12.21
Fully encapsulated with large copper-coated soldering tabs and special trim alignment marks. Trim line spaced 0.068 in (1.73 mm) from hole center.							