RESIDUAL STRESS MEASUREMENTS ON A FLAT STEEL SPRING

EMS-162L, Structure and Characterization of Materials Laboratory

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Objective: Measure the biaxial residual stress in the surface of a flat steel spring

Sample: Flat spring steel, approximately 50 mm long, 8 mm wide, and 2 mm think. The sample was provided by the instructor.

Instrument: Scintag XDS 2000 x-ray powder diffractometer

Technique: X-ray powder diffraction, $\sin^2\psi$ technique, which is defined by

$$\sigma = \frac{E}{(1+\nu)\sin^2\psi}\left(\frac{d_i - d_n}{d_n}\right) \quad \textbf{(1)}$$

where E is Young's modulus, ν is Poisson's ratio, ψ is the tilt of the sample, d_n is the d-spacing measured when $\psi=0$ and d_i is the d-spacing measured for each different setting of ψ. This technique involves scanning the same peak multiple times, each time with a different sample tilt ψ. The stress is obtained from an analysis of the small shifts in the peak positions.

Procedure: An initial analysis of a stress-free iron powder was used to confirm that the instrument would give accurate results for the spring steel. This sample was made by placing a small amount of iron powder on a glass slide then adding a few drops of methanol to help disperse the powder. After the methanol dried the powder was evenly distributed over the slide.

The steel sample was carefully deburred then mounted to ensure that it was at the correct height.

The parameters for the data collection used for both samples were:

λ: 0.1540562 nm (Cu $K_{\alpha 1}$)
Receiving and scatter slits: 0.05 and 0.1 mm
Step size: 0.05 degrees 2θ
Scan rate: 1 degree per minute
Scan range: 80 to 85 degrees 2θ (2θ=82.3 for the (211) peak)
ψ: from -30 to 30 degrees in 11 steps, in increments of $\sin^2\psi$

Analysis: Figure 1 shows the change in d-spacing as a function of sample tilt ψ for the spring steel sample.

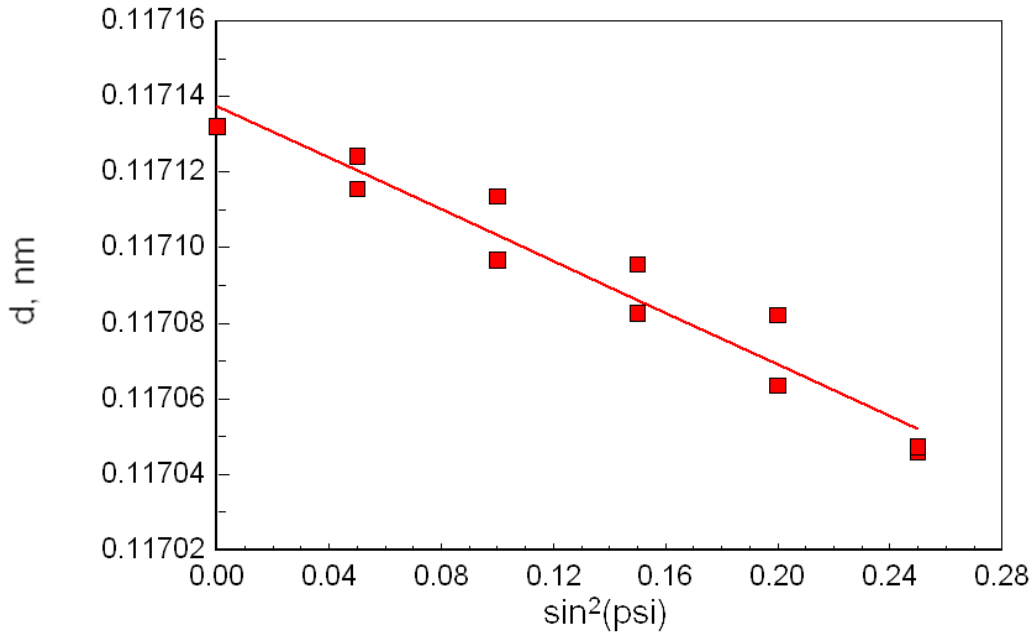

Figure 1 Results of the residual stress scans of the steel spring.

The stress was obtained from a regression analysis of the data plotted in figure 1. The slope of this line is given by

$$\text{Slope} = \frac{\sigma}{E}(1+\nu)d_n \qquad \textbf{(2)}$$

and the elastic constants are

E = 206.9 GPa
ν=0.19.

Final Result: The stress measured in the iron powder was -12.5 MPa with a standard deviation of 29.4 MPa. This is close to 0 MPa and indicates that the diffractometer is working properly. The biaxial residual stress for the steel spring was -506 MPa with a standard deviation of 32 MPa.

Cost: The cost of performing the measurements and the analysis is $448. An itemized list of expenses is attached.

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Description: Budgeting and Costs of the EMS-162L Experiments

8. Experiment 5, X-ray Diffraction, Residual Stress

1. Laboratory Instrumentation and Analyses

	Instrumentation Costs			Technician Support			
Instrument	**Rate**	**Hours**	**Cost**	**Rate**	**Hours**	**Cost**	**Total**
SEM	$30.00	0	$0.00	$40.00	0	$0.00	$0.00
TEM	$27.00	0	$0.00	$40.00	0	$0.00	$0.00
STEM	$40.00	0	$0.00	$40.00	0	$0.00	$0.00
XRD	$15.00	3	$45.00	$40.00	0	$0.00	$45.00
SAXS	$20.00	0	$0.00	$40.00	0	$0.00	$0.00
OM	$0.00	0	$0.00	$40.00	0	$0.00	$0.00
AM	$0.00	0	$0.00	$40.00	0	$0.00	$0.00
XRR	$0.00	0	$0.00	$40.00	0	$0.00	$0.00
FTIR	$0.00	0	$0.00	$40.00	0	$0.00	$0.00
Raman	$25.00	0	$0.00	$0.00	0	$0.00	$0.00
XLA	$10.00	0	$0.00	$40.00	0	$0.00	$0.00
	Total:	3	$45.00	Total:	0	$0.00	$45.00

2. Supplies and Services

	Cost	Percentage
Metallography Supplies:	$0.00	0.00%
EM Sample Preparation:	$0.00	0.00%
Chemicals:	$0.00	0.00%
Film and Darkroom:	$0.00	0.00%
Office and Computer Supplies:	$20.00	100.00%
Other:	$0.00	0.00%
Total:	$20.00	100.00%

3. Personnel

Engineer Rate: $42.62 per hour

	Hours	Cost	Percentage
Research, Preparation:	1	$42.62	11.11%
Laboratory Work:	3	$127.85	33.33%
Data Analysis:	1	$42.62	11.11%
Report Preparation:	3	$127.85	33.33%
Report Presentation:	1	$42.62	11.11%
Other:	0	$0.00	0.00%
Total:	9	$383.54	100.00%

4. Summary

	Cost	Percentage
Instrumentation and Analyses:	$45.00	10.03%
Supplies and Services:	$20.00	4.46%
Personnel:	$383.54	85.51%
Total:	$448.54	100.00%