



Internal Friction and Backscattering Measurements of CW Stainless Steel

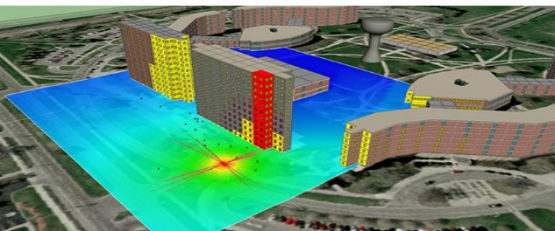
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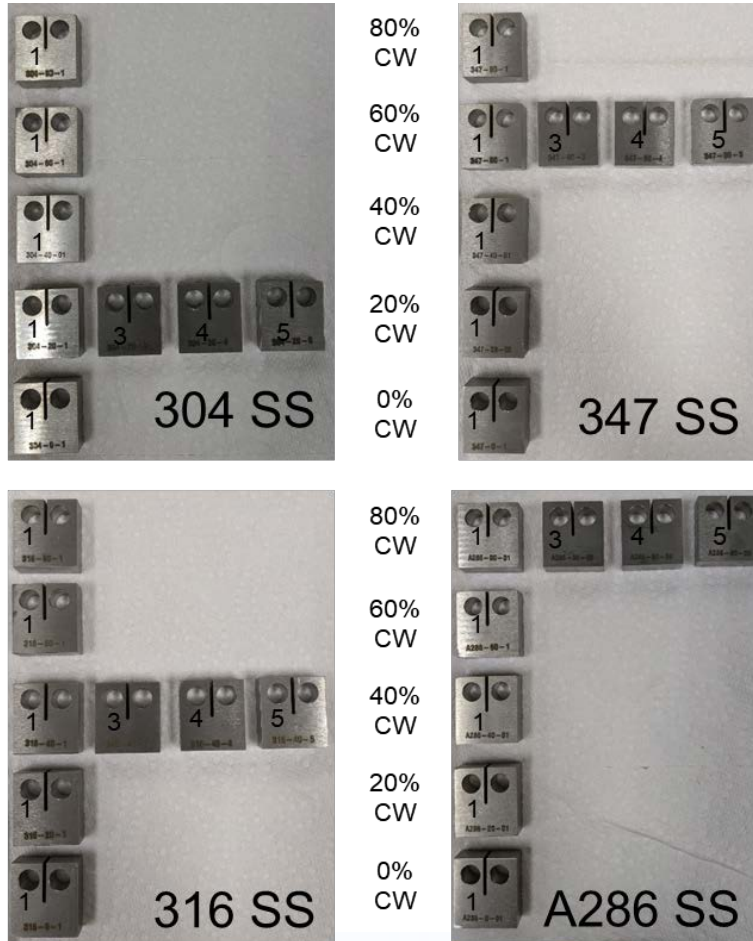
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Samples and Ultrasonic Measurements

Samples



Ultrasonic Internal Friction Measurement

- 2.25 MHz
- 3.5 MHz

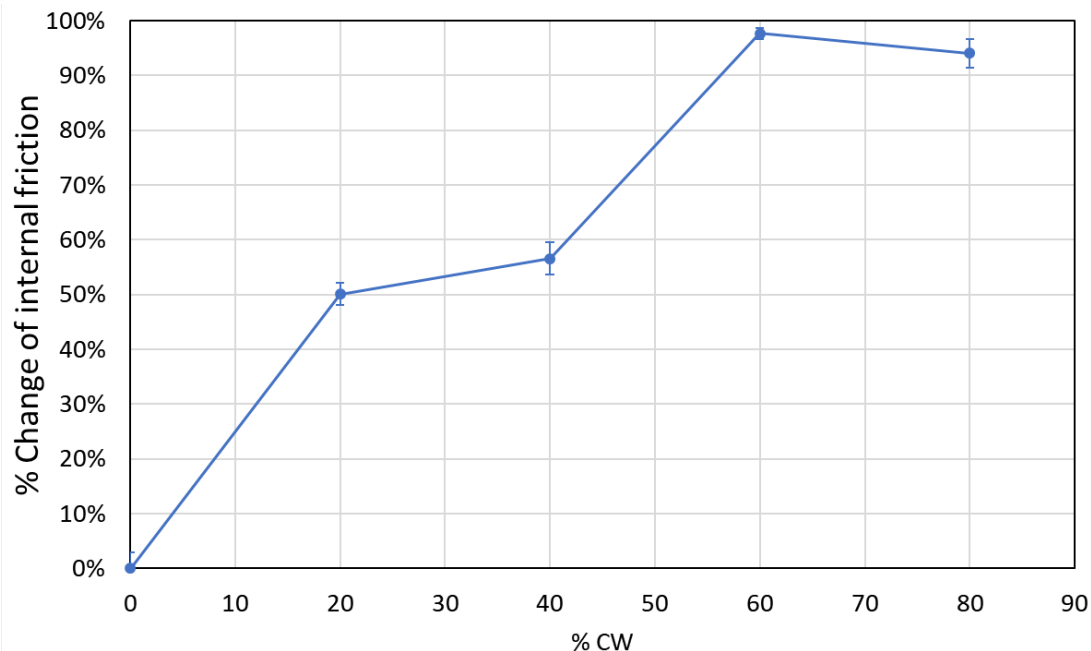
Ultrasonic Backscattering Measurements

- 15 MHz



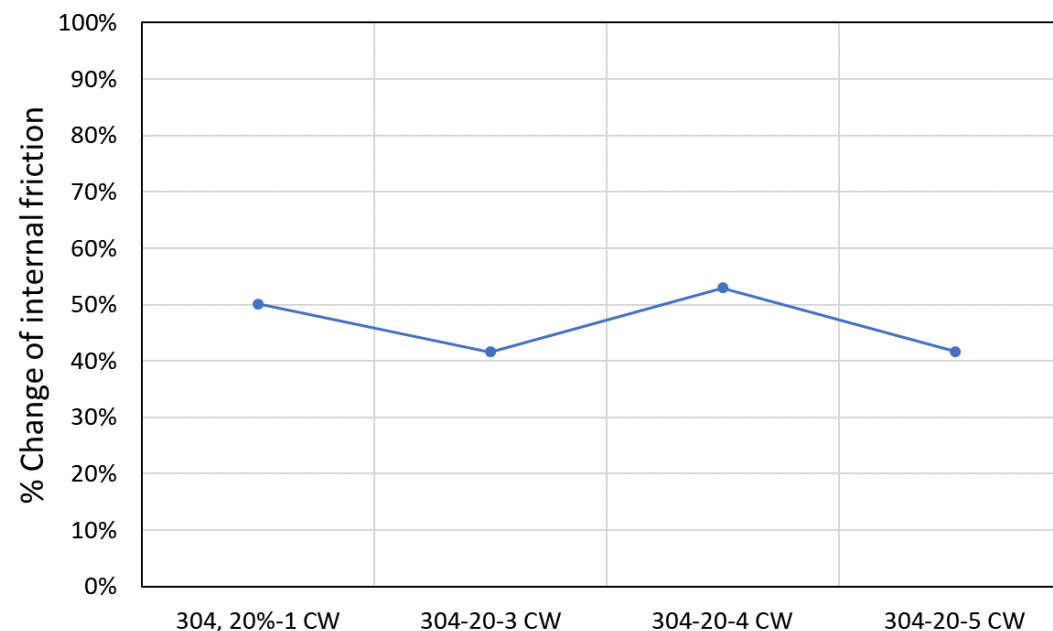
Internal Friction, 304 SS

Internal Friction 304 SS vs % CW



Sample ID	% CW	% change from 0% CW	Standard Error	Standard Error (%)
304, 0% - 1 CW	0	0%	0.013	2.9%
304, 20% - 1 CW	20	50%	0.014	2.0%
304, 40% - 1 CW	40	57%	0.022	3.0%
304, 60% - 1 CW	60	98%	0.010	1.1%
304, 80% - 1 CW	80	94%	0.024	2.7%

Reproducibility Internal Friction 304 SS 20% CW

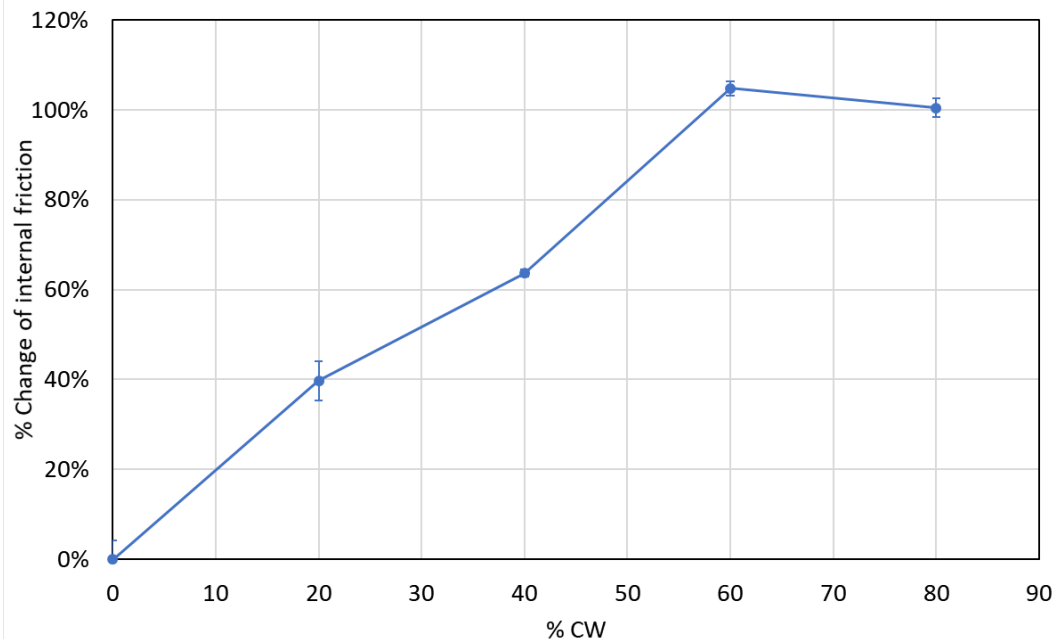


Sample	% change from 0% CW	Standard Error	Standard Error (%)
304, 0% - 1 CW	50%	0.014	2.0%
304-20-3 CW	42%	0.014	2.1%
304-20-4 CW	53%	0.022	3.1%
304-20-5 CW	42%	0.012	1.9%



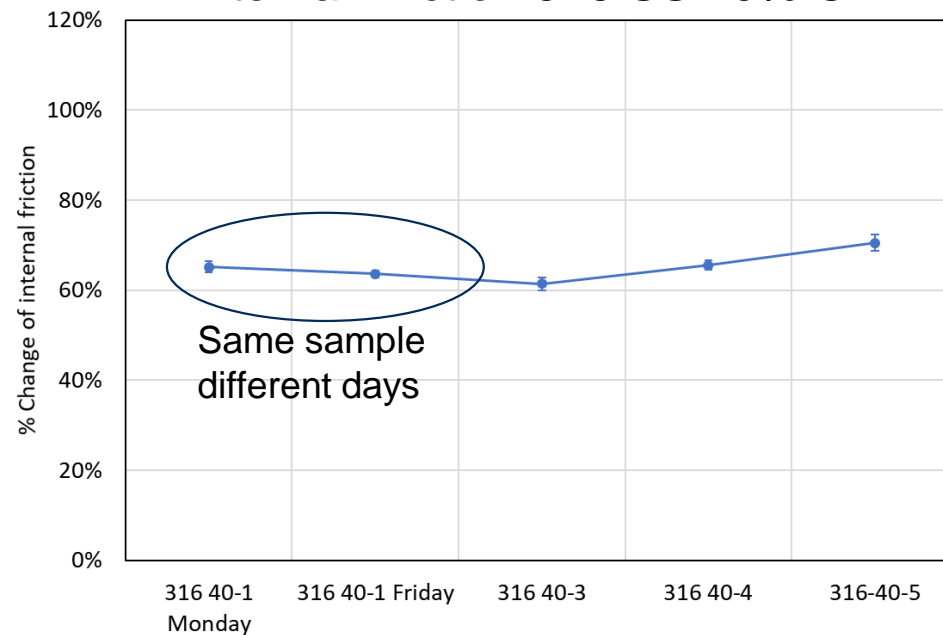
Internal Friction, 316 SS

Internal Friction 316 SS vs % CW



Sample ID	% CW	% change from 0% CW	Standard Error	Standard Error (%)
316, 0% - 1 CW	0	0%	0.021	4.6%
316, 20% - 1 CW	20	42%	0.032	5.0%
316, 40% - 1 CW	40	70%	0.007	1.0%
316, 60% - 1 CW	60	117%	0.017	1.8%
316, 80% - 1 CW	80	113%	0.024	2.5%

Reproducibility Internal Friction 316 SS 40% CW

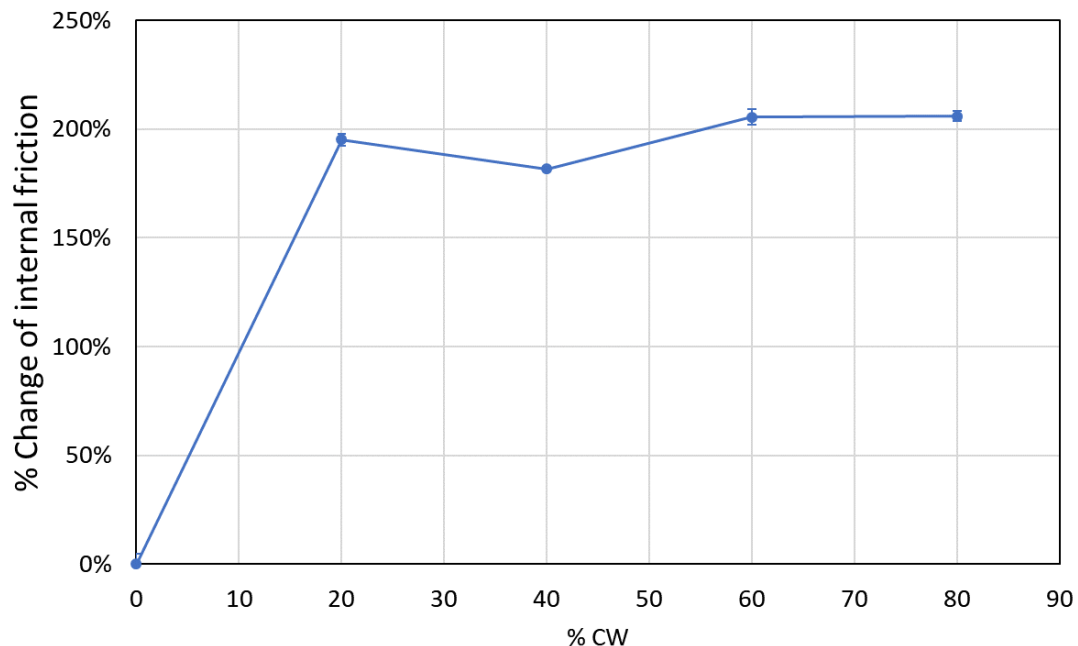


Sample	% change from 0% CW	Standard Error	Standard Error (%)
316 40%-1 Monday	73%	0.008	1.1%
316 40%-1 Friday	70%	0.007	1.0%
316 40%-3	65%	0.012	1.6%
316 40%-4	69%	0.008	1.1%
316-40%-5	76%	0.016	2.1%



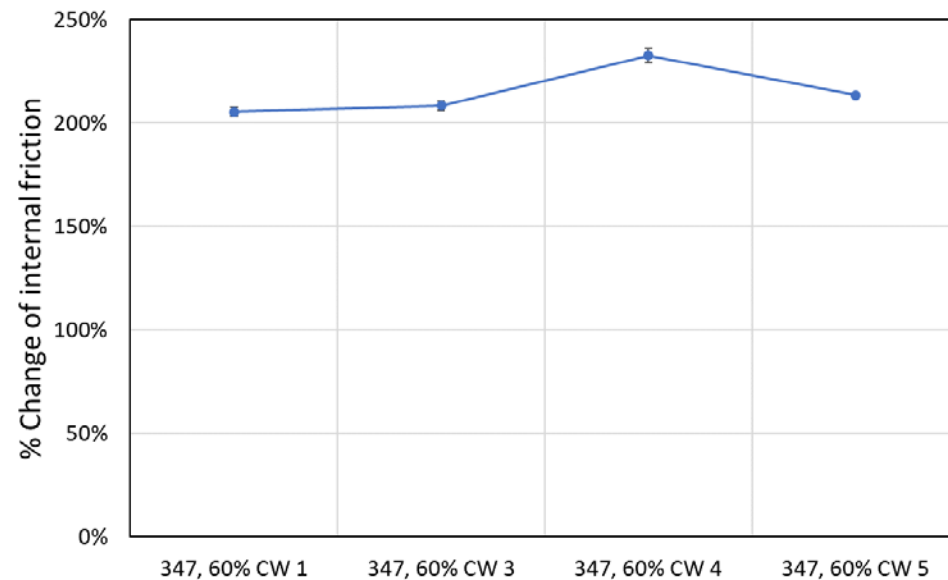
Internal Friction, 347 SS

Internal Friction 347 SS vs % CW



Sample ID	% CW	% change from 0% CW	Standard Error	Standard Error (%)
347, 0% CW	0	0%	0.012	4.6%
347, 20% CW 1	20	195%	0.022	2.7%
347, 40% CW	40	182%	0.006	0.8%
347, 60% CW 1	60	206%	0.030	3.7%
347, 80% CW	80	206%	0.018	2.2%

Reproducibility Internal Friction 347 SS 60% CW

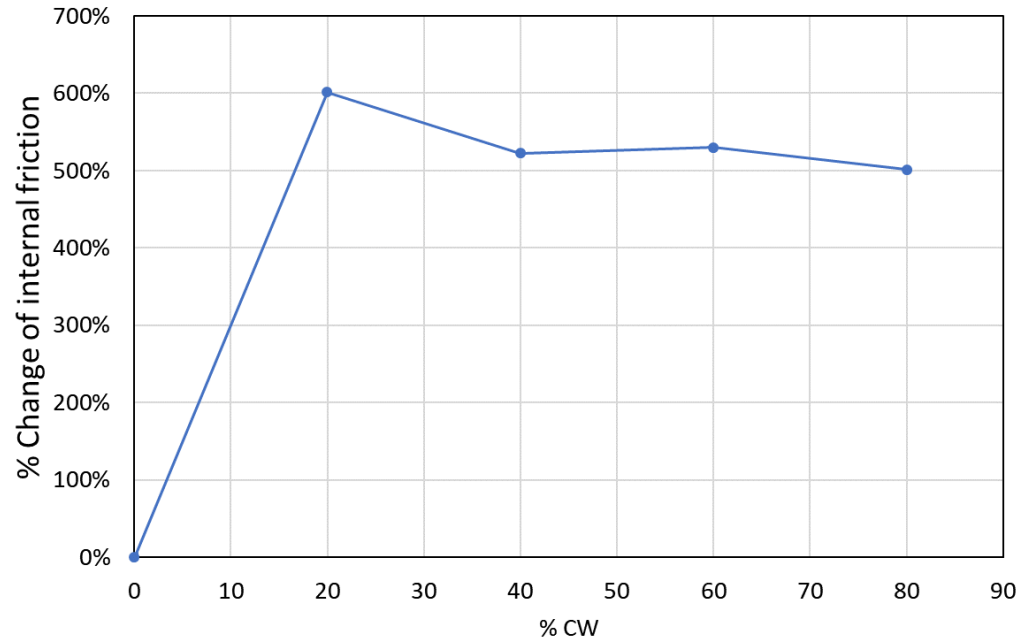


Sample	% change from 0% CW	Standard Error	Standard Error (%)
347, 60% CW 1	206%	0.030	3.7%
347, 60% CW 3	208%	0.019	2.3%
347, 60% CW 4	233%	0.019	2.1%
347, 60% CW 5	214%	0.029	3.5%



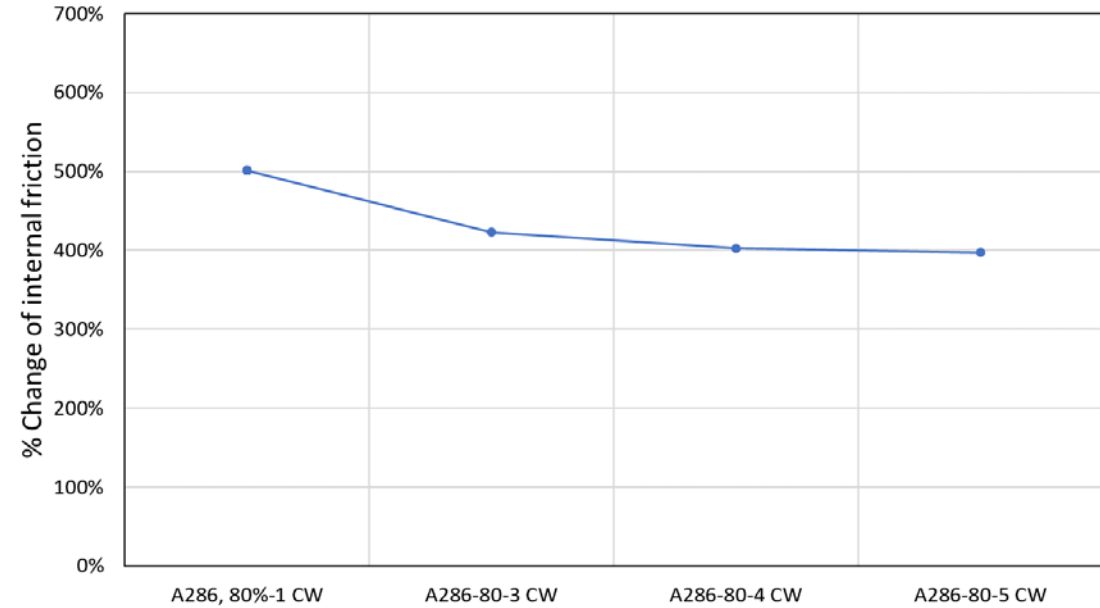
Internal Friction, A286 SS

Internal Friction A286 SS vs % CW



Sample ID	% CW	% change from 0% CW	Standard Error	Standard Error (%)
A286, 0% CW	0	0%	0.010	4.6%
A286, 20% CW	20	601%	0.023	1.6%
A286, 40% CW	40	523%	0.023	1.8%
A286, 60% CW	60	530%	0.013	1.0%
A286, 80%-1 CW	80	501%	0.025	2.0%

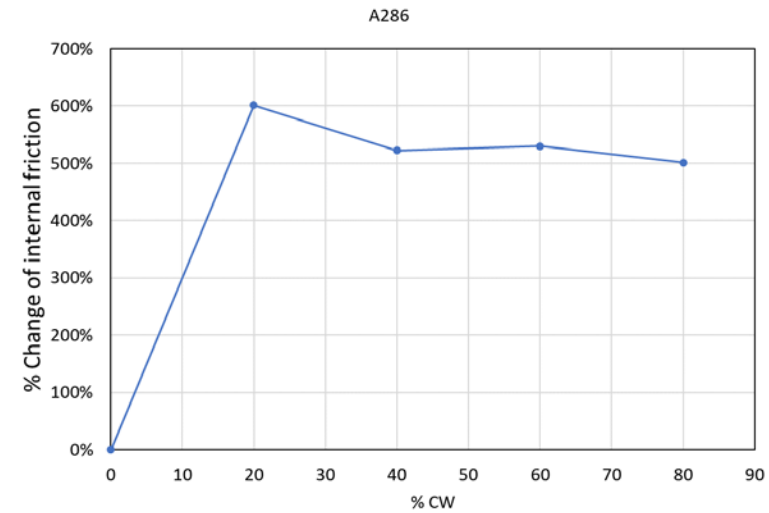
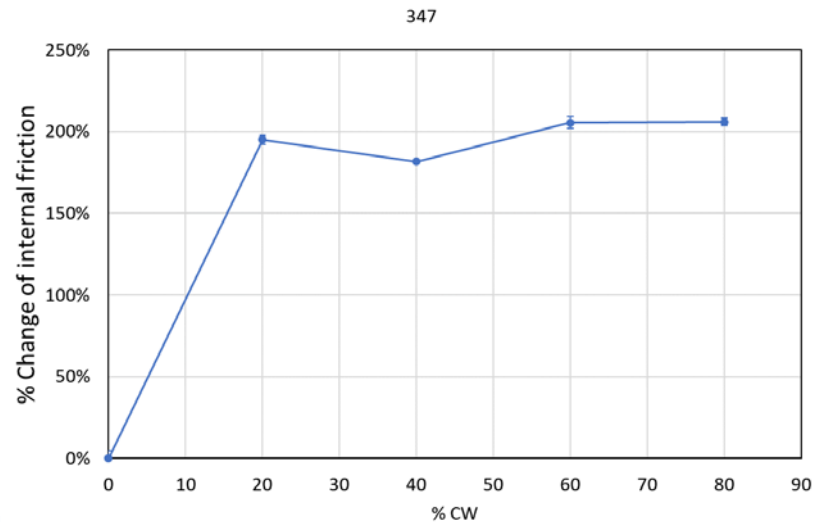
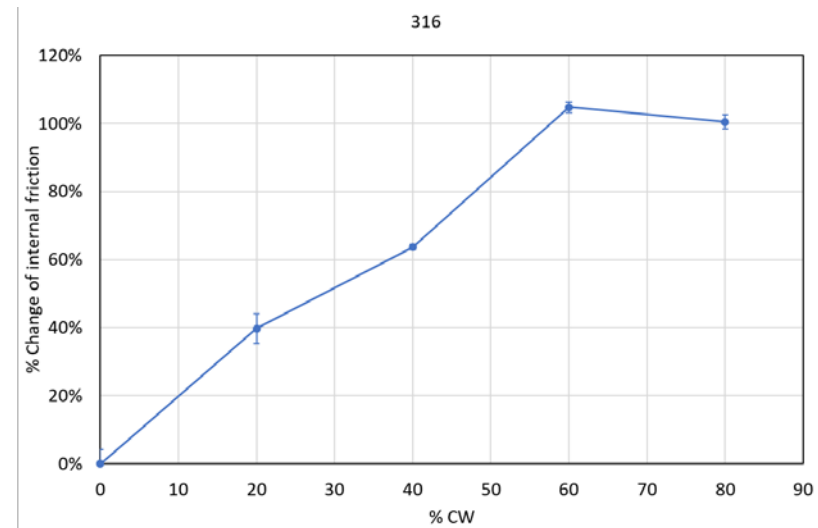
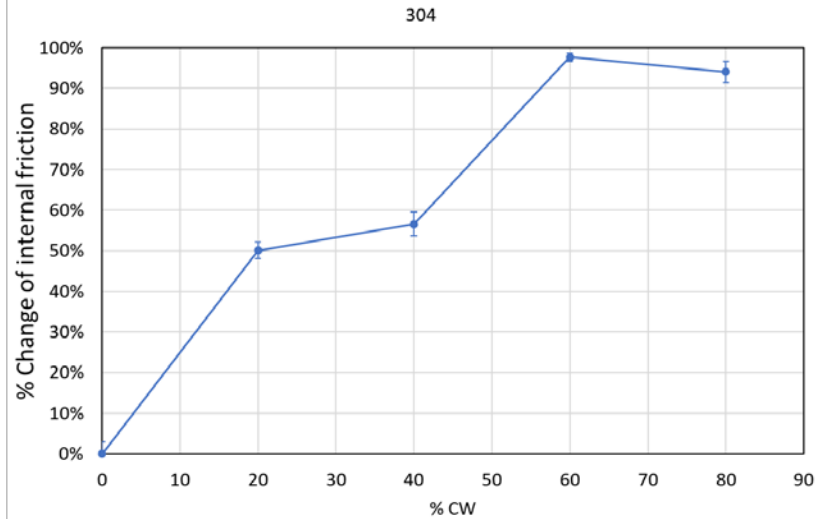
Reproducibility
Internal Friction A286 SS 80% CW



Sample	% change from 0% CW	Standard Error	Standard Error (%)
A286, 80%-1 CW	501%	0.025	2.0%
A286-80-3 CW	423%	0.007	0.6%
A286-80-4 CW	403%	0.032	3.1%
A286-80-5 CW	397%	0.028	2.7%

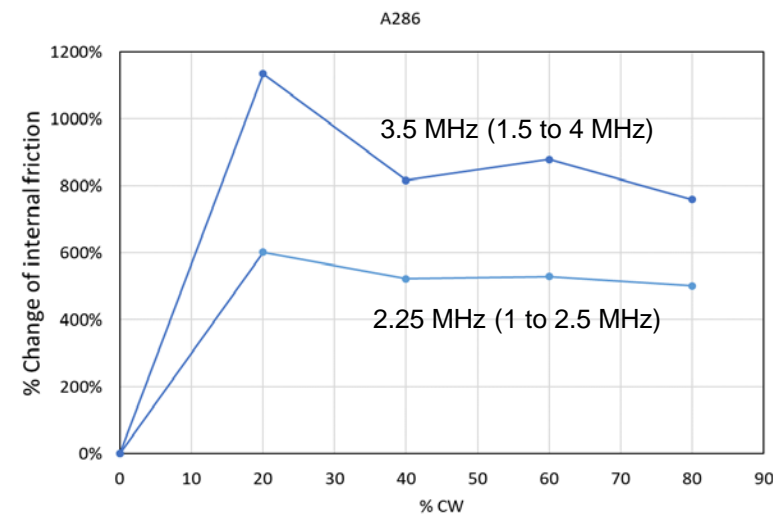
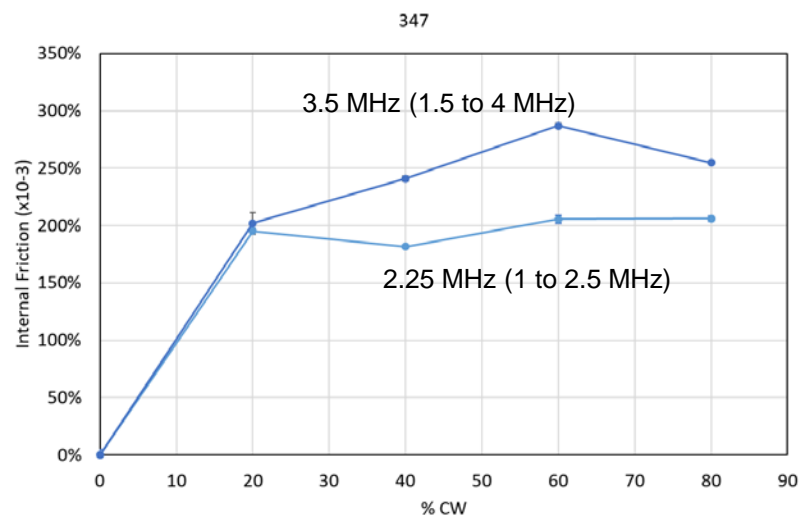
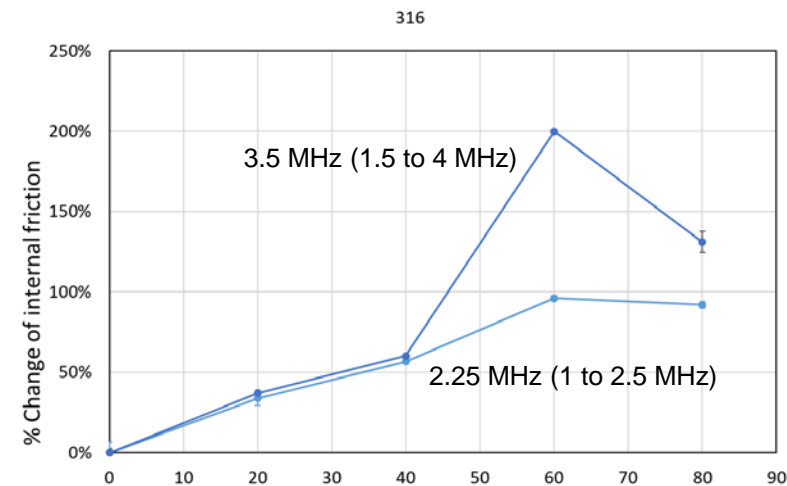
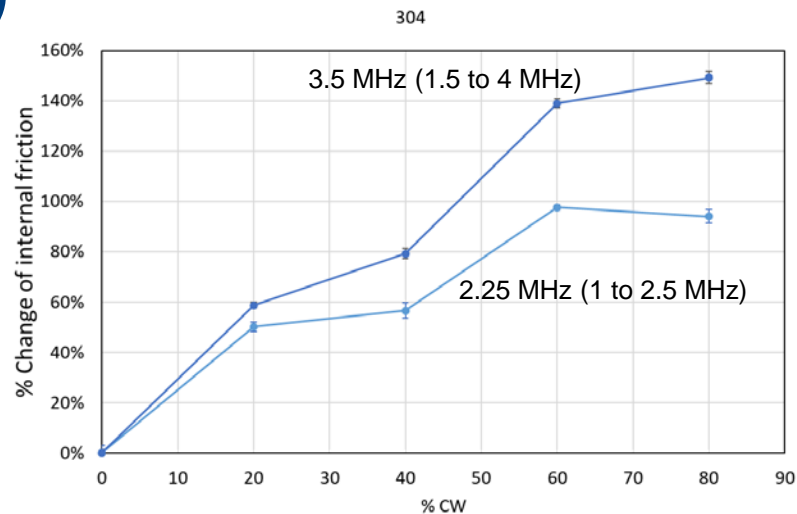


Internal Friction vs. % CW for 304, 316, 347, A286 (2.25 MHz)





Internal Friction vs. % CW for 304, 316, 347, A286 (2.25 MHz and 3.5 MHz)





Internal friction, 3.5 MHz Data Tables

Sample ID	% CW	% change from 0% CW	Standard Error	Standard Error (%)
304, 0% - 1 CW	0	0%	0.005	1.3%
304, 20% - 1 CW	20	59%	0.006	1.1%
304, 40% - 1 CW	40	79%	0.012	1.9%
304, 60% - 1 CW	60	139%	0.015	1.7%
304, 80% - 1 CW	80	149%	0.021	2.4%

Sample ID	% CW	% change from 0% CW	Standard Error	Standard Error (%)
347, 0% CW	0	0%	0.002	1.0%
347, 20% CW 1	20	202%	0.060	9.5%
347, 40% CW	40	241%	0.017	2.3%
347, 60% CW 1	60	287%	0.015	1.8%
347, 80% CW	80	255%	0.008	1.0%

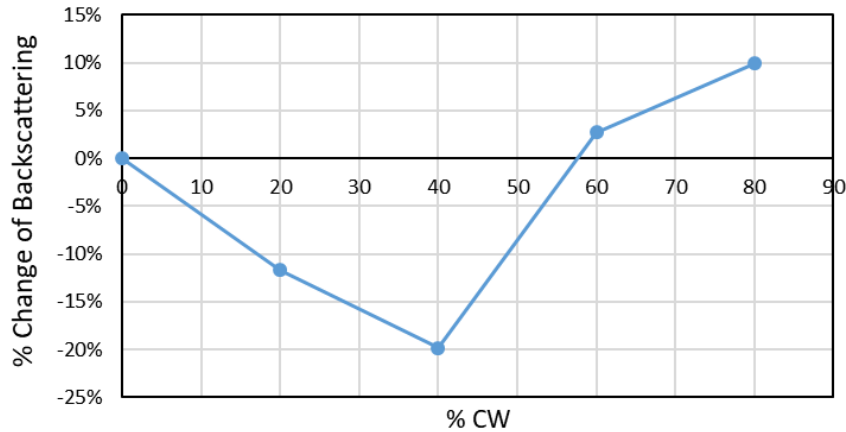
Sample ID	% CW	% change from 0% CW	Standard Error	Standard Error (%)
316, 0% - 1 CW	0	0%	0.010	2.4%
316, 20% - 1 CW	20	37%	0.004	0.7%
316, 40% - 1 CW	40	60%	0.005	0.8%
316, 60% - 1 CW	60	200%	0.013	1.0%
316, 80% - 1 CW	80	131%	0.063	6.6%

Sample ID	% CW	% change from 0% CW	Standard Error	Standard Error (%)
A286, 0% CW	0	0%	0.003	1.7%
A286, 20% CW	20	1136%	0.011	0.5%
A286, 40% CW	40	817%	0.015	1.0%
A286, 60% CW	60	880%	0.016	0.9%
A286, 80%-1 CW	80	759%	0.022	1.5%

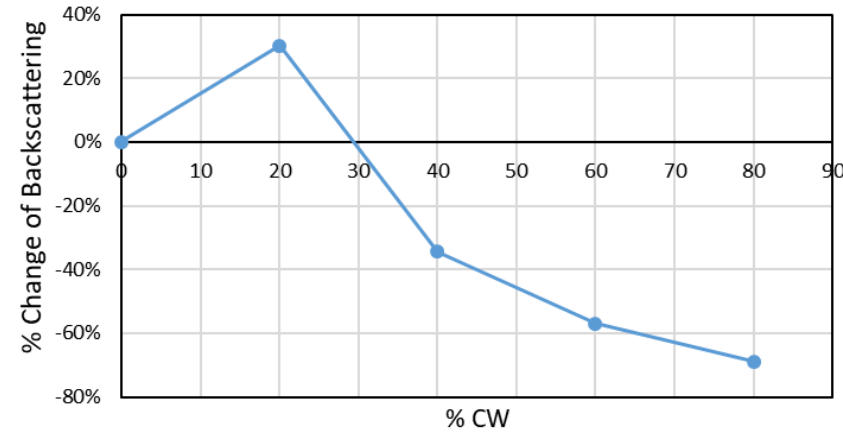


Backscattering vs cold work

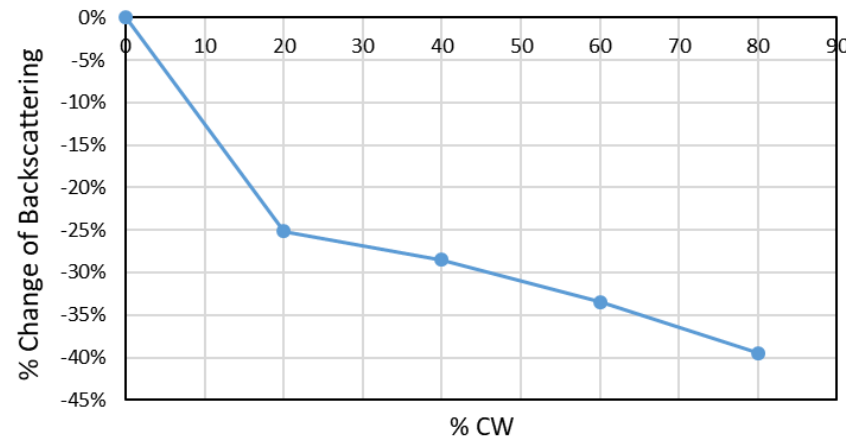
304



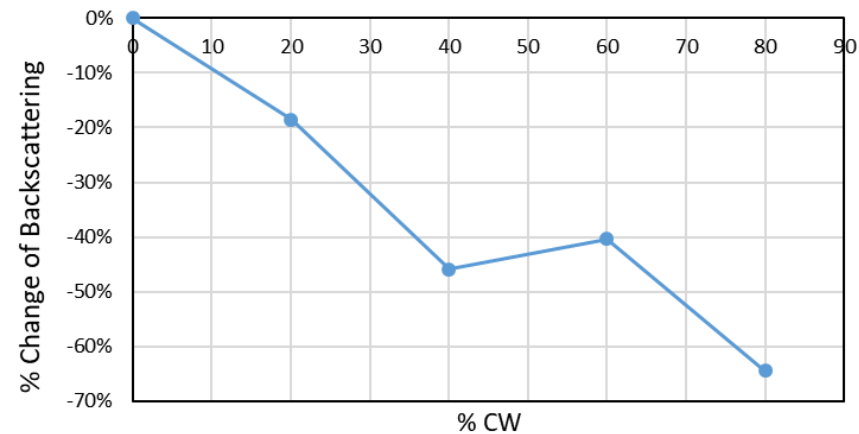
316



347



A 286





Backscattering data tables

Sample ID	% CW	% change from 0% CW	Sample ID	% change from 0% CW	Sample ID	% change from 0% CW	Sample ID	% change from 0% CW
304, 0% - 1 CW	0	0%	316, 0% - 1 CW	0%	347, 0% CW	0%	A286, 0% CW	0%
304, 20% - 1 CW	20	-12%	316, 20% - 1 CW	30%	347, 20% CW 1	-25%	A286, 20% CW	-18%
304, 40% - 1 CW	40	-20%	316, 40% - 1 CW	-34%	347, 40% CW	-28%	A286, 40% CW	-46%
304, 60% - 1 CW	60	3%	316, 60% - 1 CW	-57%	347, 60% CW 1	-33%	A286, 60% CW	-40%
304, 80% - 1 CW	80	10%	316, 80% - 1 CW	-69%	347, 80% CW	-39%	A286, 80%-1 CW	-64%



Conclusions

- Microstructural changes caused by CW can be measured by internal friction
 - 150% change for 304 SS
 - 200% change for 316 SS
 - 300% change for 347 SS
 - 1100% change for A286 SS
- Measurements are highly reproducible and precise
- Higher frequency (3.5 MHz) measurements of internal friction are generally more sensitive to CW than lower frequency (2.25 MHz)
- Backscattering measurements are sensitive changes that occur in CW
- Need to perform microscopy to determine microstructure changes in dislocation and grain size