Damage Precursors of Acoustic Emission Parameters from Fatigue Loading

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Acknowledgments

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3. Dr. Victor Ontiveros (Former PhD Student)
4. Ms. Christine Sauerbrunn (Former MS Student)
5. Dr. Mehdi Amiri (Former Postdoc)
6. Dr. Ali Kahirdeh (Current Postdoc)
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9. Prof. Mohammad Modarres (PI)

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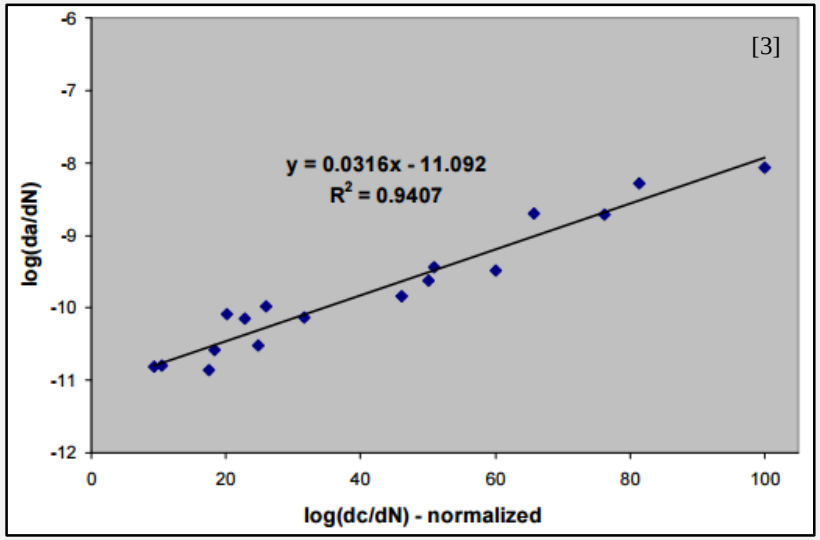
Objectives

- Describe damage using surrogate indicators of damage such as acoustic emission (AE)
- Process raw AE features to prediction fatigue damage
- Define damage and its endurance in the context of AE features
- Search for applications to Prognosis and Health Management (PHM) of structures

Motivation: AE Features and Suggesting Approaches

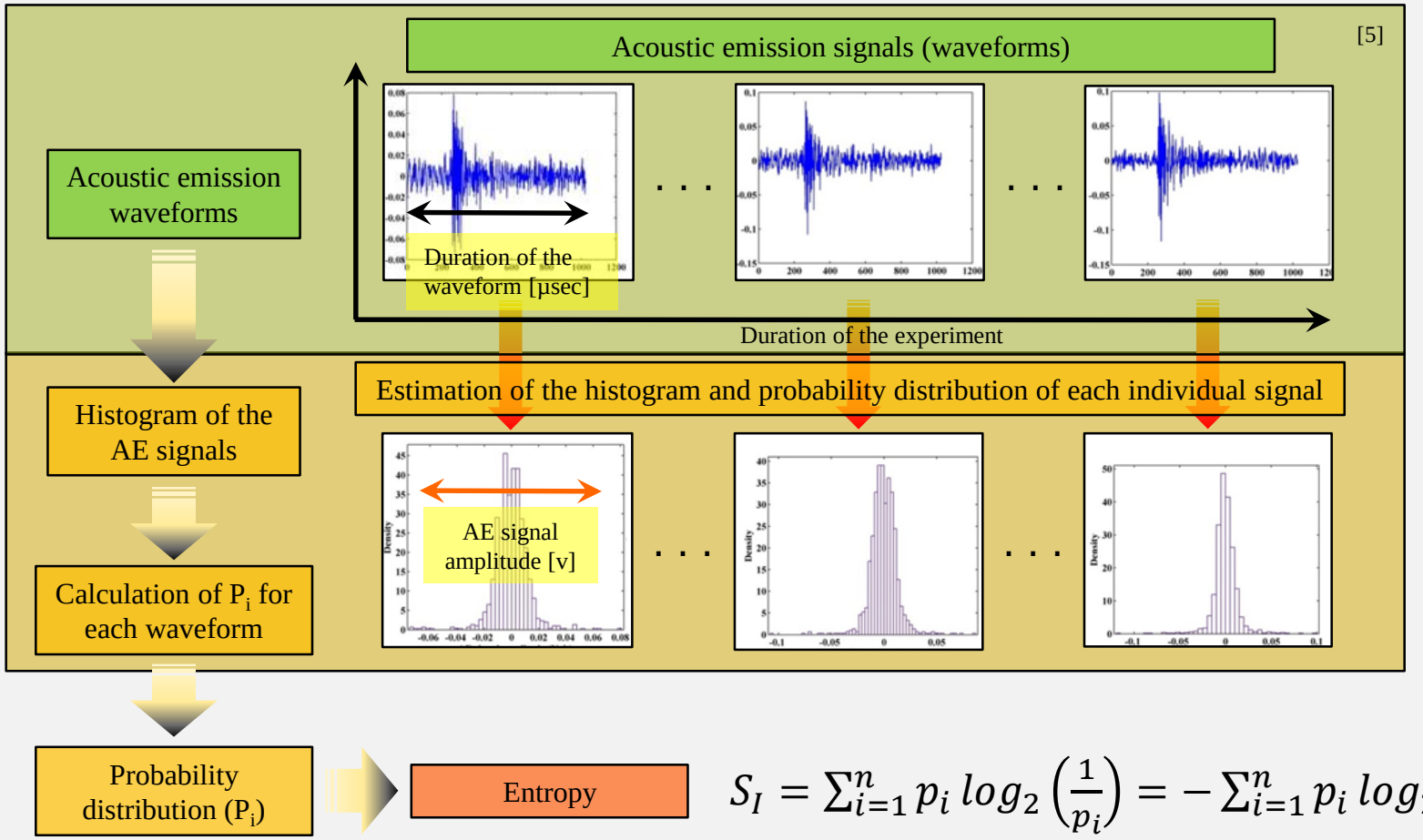


Crack growth correlation with one of AE features (AE count)

Q. How to improve AE features in order to represent damage
☞ Information entropy

[3] A. Kshtgar and M. Modarres, Acoustic Emission-Based Fatigue Crack Growth Prediction, Reliability and Maintainability Symposium (RAMS), 2013 Proceedings-Annual, p.1-5

Information Entropy: Analysis Procedure



$$S_I = \sum_{i=1}^{n} p_i \, log_2\left(\frac{1}{p_i}\right) = -\sum_{i=1}^{n} p_i \, log_2(p_i)$$

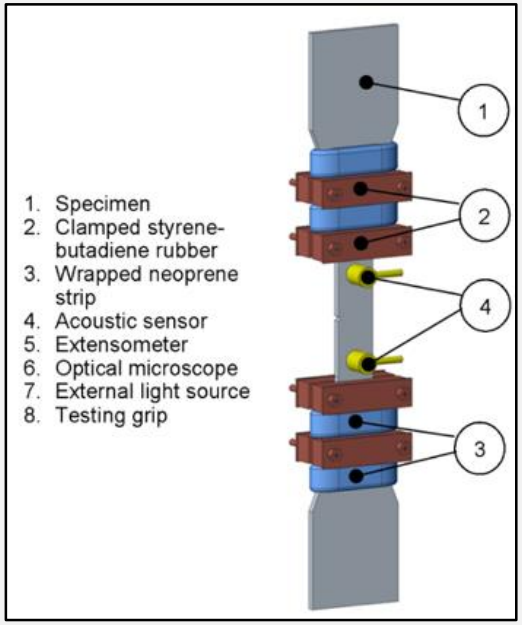
[5] Ali Kahirdeh, Christine Sauerbrunn, Mohammad Modarres, Proceedings of the 35th International Workshop on Bayesian Inference and Maximum Entropy Methods in Science and Engineering, MaxEnt_2015, Potsdam, NY, 2015

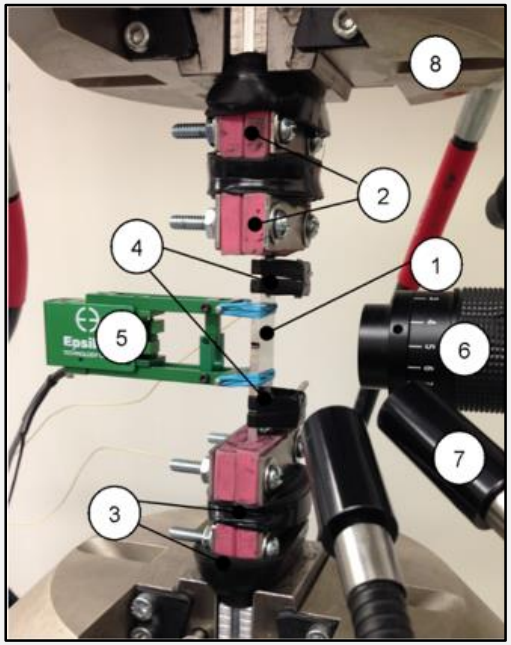
Information Entropy: Material & Test Setup

- Material / Specimen: Al alloy 7075-T6 / Dogbone ASTM E466

Element	Al	Zn	Mg	Cu	Cr	Fe	Mn	Si	Ti	V	Zr	Other
Composition (wt %)	89.7	5.7	2.6	1.4	0.20	0.15	0.08	0.06	0.02	0.01	0.01	0.05
Material Property	Ultimate Strength (MPa)				Yield Strength (MPa)				Elastic Modulus (GPa)			
Property Value	587				538				67.8			

[6]





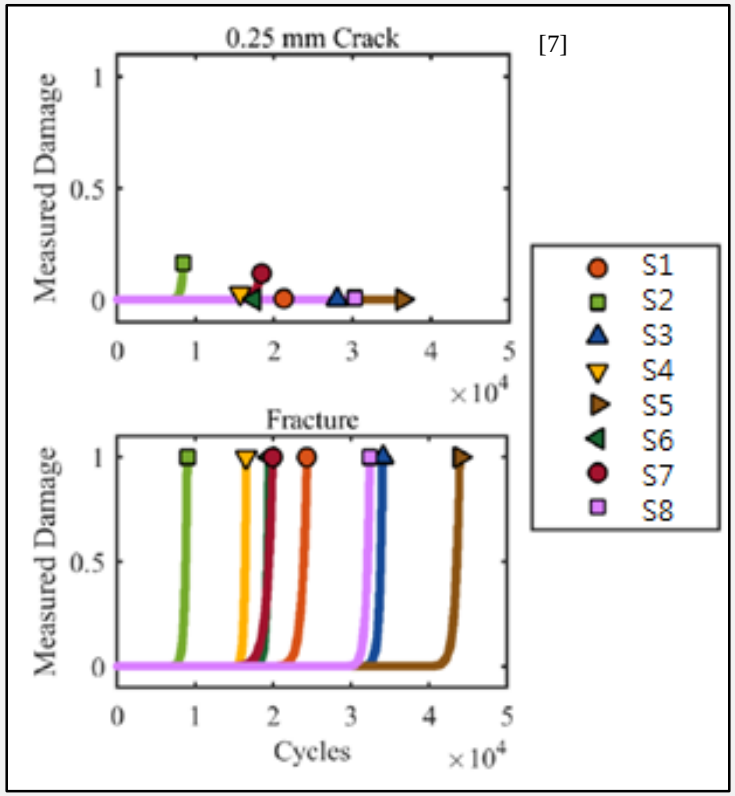
- Dogbone specimen with round notch (1 mm radius)
- K_t=2.61
- Eraser and neoprene rubber bands were used for mechanical damper for AE signal noise reduction

[6] Sauerbrunn, Christine M., et al. "Damage Assessment Using Information Entropy of Individual Acoustic Emission Waveforms during Cyclic Fatigue Loading." *Applied Sciences* 7.6 (2017): 562

Information Entropy: Measurement of Damage

- Reference damage is computed by using modulus degradation

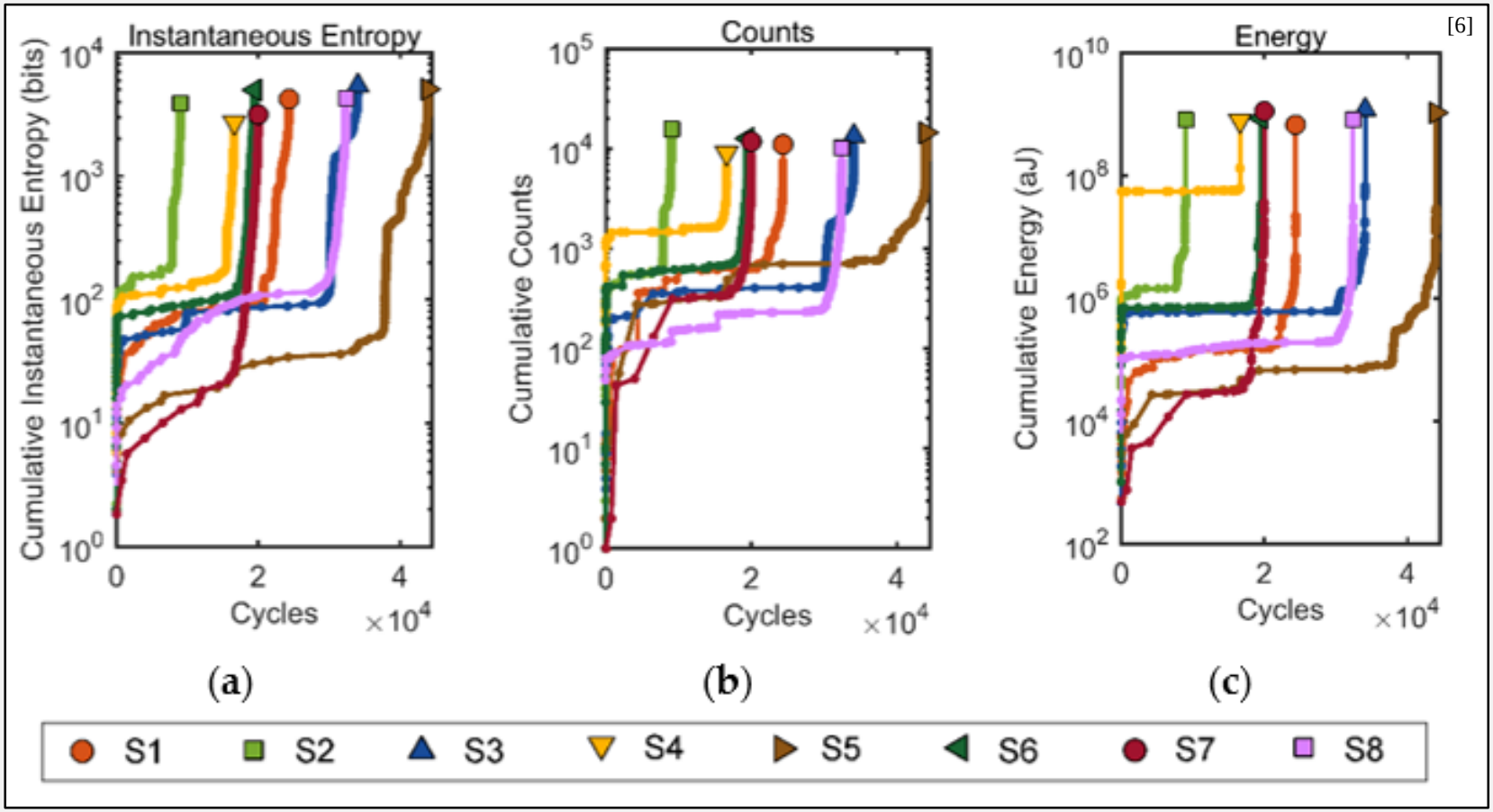
$$MDD^{*} = \frac{E_i - E_0}{E_f - E_0}$$



* MDD: Modulus Degradation Damage

[7] Christine M. Sauerbrunn, Evaluation of Information Entropy from Acoustic Emission Waveforms as a Fatigue Damage Metric for Al7075-T6, 2016, University of Maryland, Master of Science Thesis

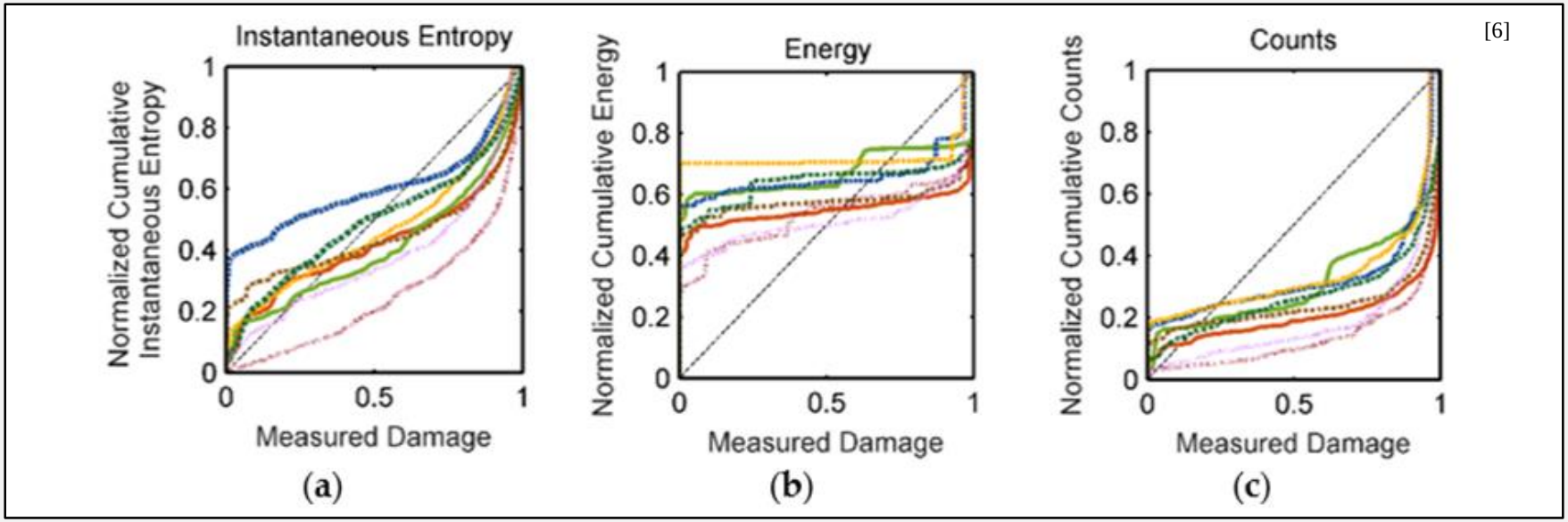
Information Entropy: Cumulative AE Features

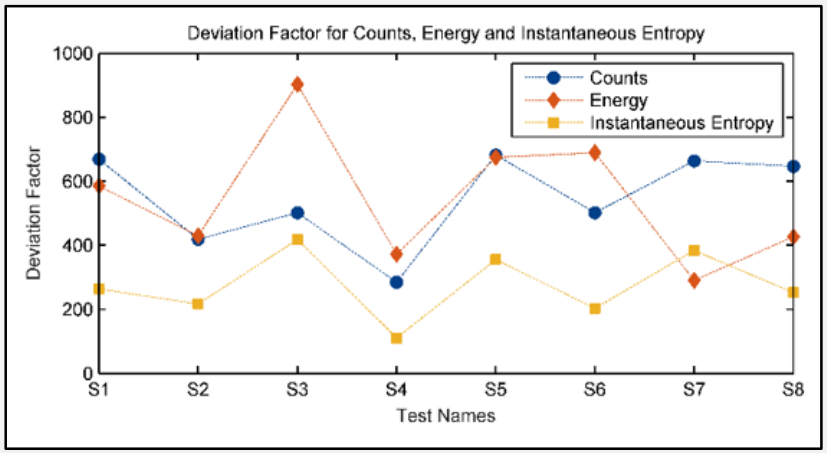


- The cumulated features were normalized for comparing with measured damage

[6] Sauerbrunn, Christine M., et al. "Damage Assessment Using Information Entropy of Individual Acoustic Emission Waveforms during Cyclic Fatigue Loading." *Applied Sciences* 7.6 (2017): 562

Information Entropy: Cumulative AE Features

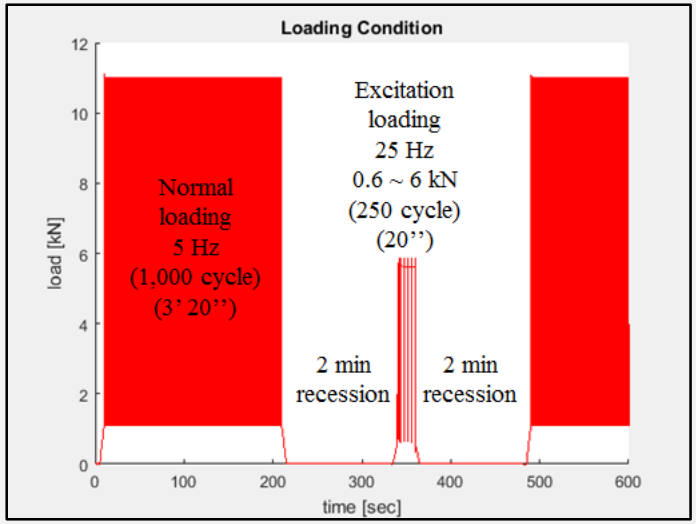




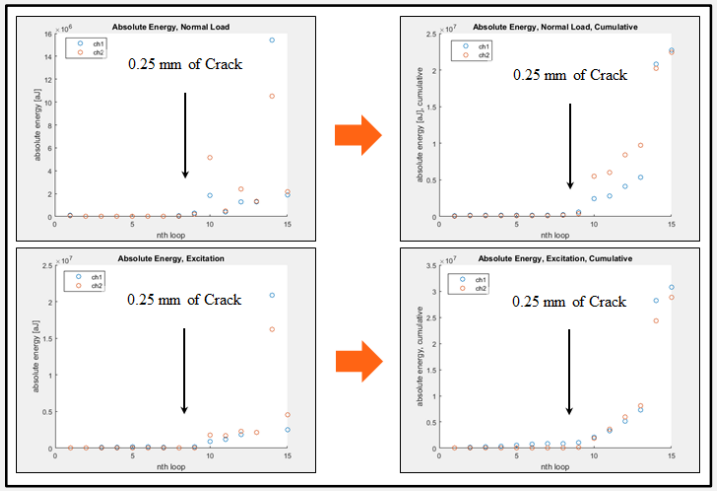
- The correlation results were evaluated with deviation factor
- The information entropy is closer than raw AE features

[6] Sauerbrunn, Christine M., et al. "Damage Assessment Using Information Entropy of Individual Acoustic Emission Waveforms during Cyclic Fatigue Loading." *Applied Sciences* 7.6 (2017): 562

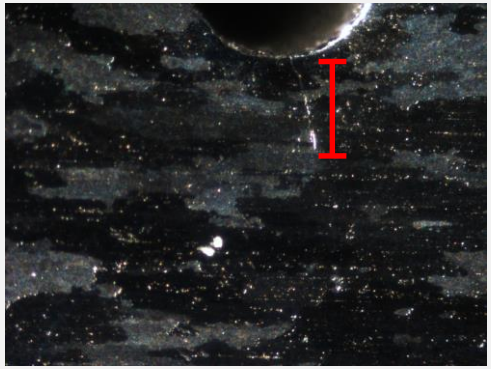
Excitation with AE Features: Analysis Procedure



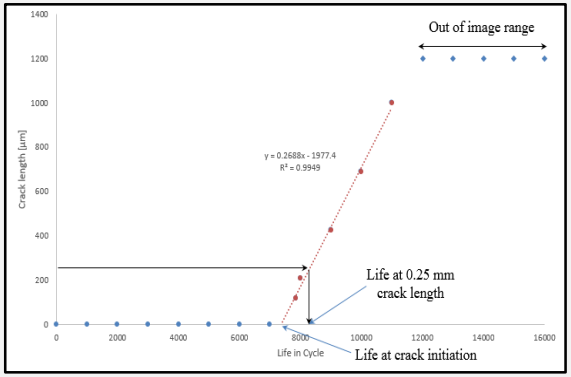
Fatigue testing combined with excitation



AE features analysis



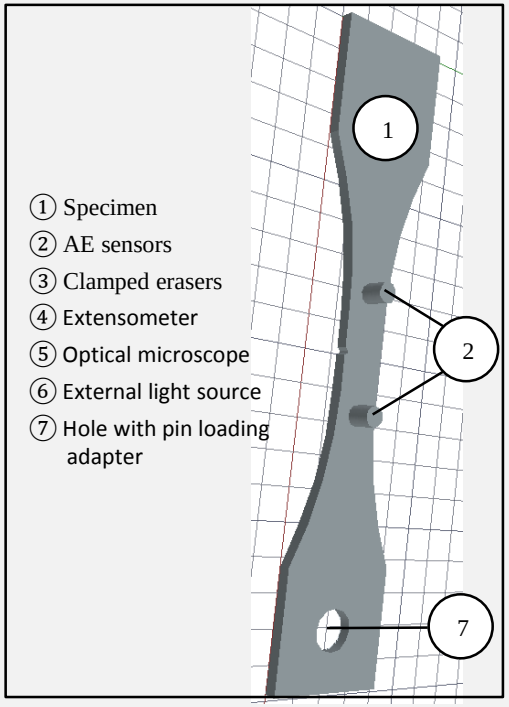
Crack length monitoring

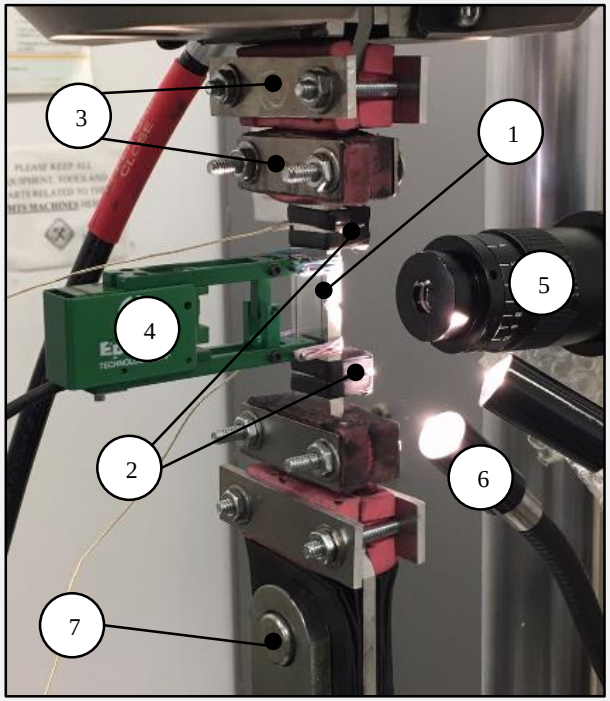


Defining fatigue life

Determine Fatigue life endurance

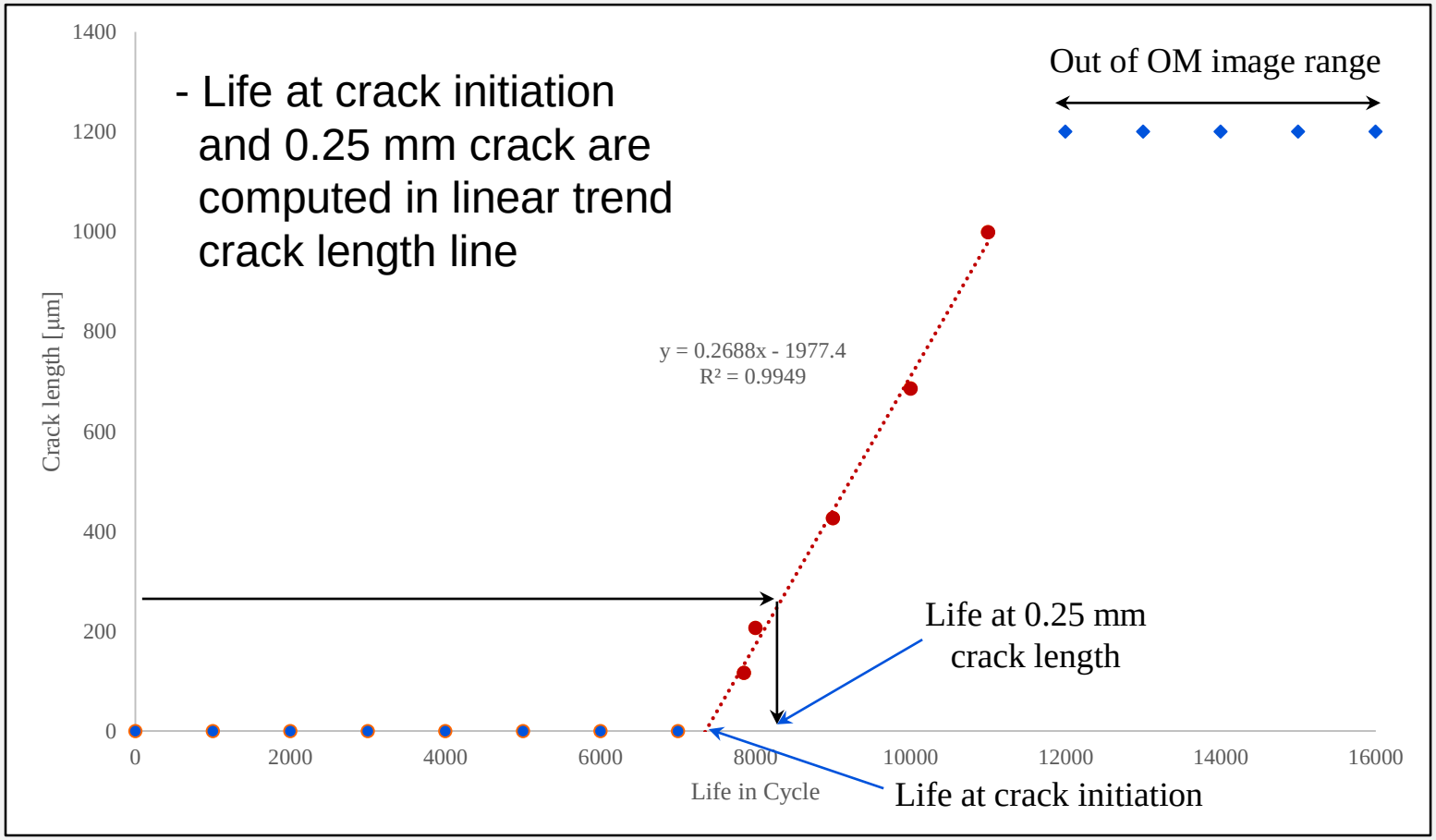
Excitation with AE Features: Material & Test Setup





- Dogbone specimen with V shape notch
- K_t=4.05
- Pin-in-hole loading with eraser damper renovated noise reduction

Excitation with AE Features: Crack Growth Analysis



Excitation with AE Features: AE Features

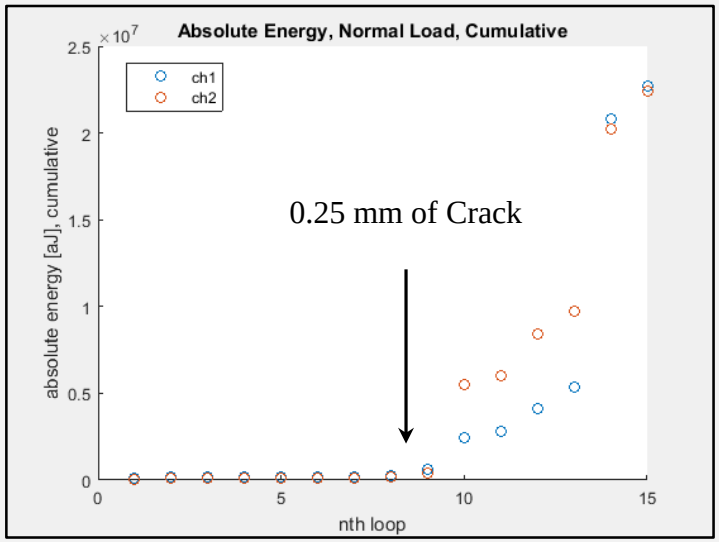
- AE Features Analysis

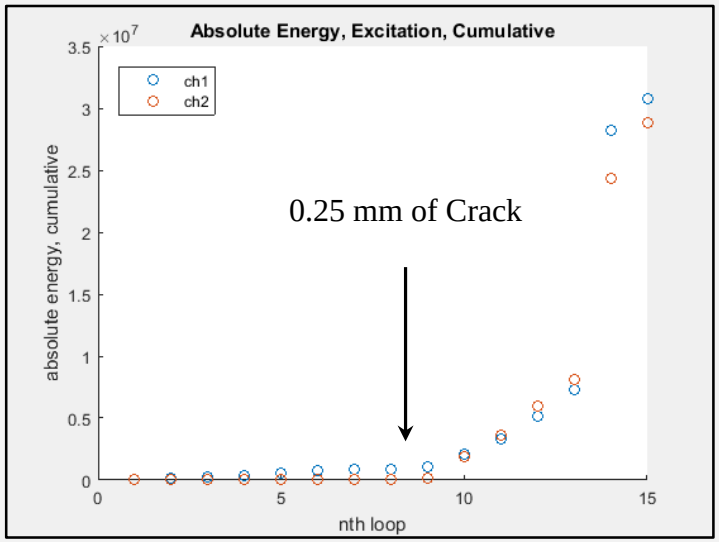
- Selected AE features: hit, count, and absolute energy

- For each normal and excitation loads in every loop, cumulative AE features calculated

- Crack initiation point coincides with AE feature curve change

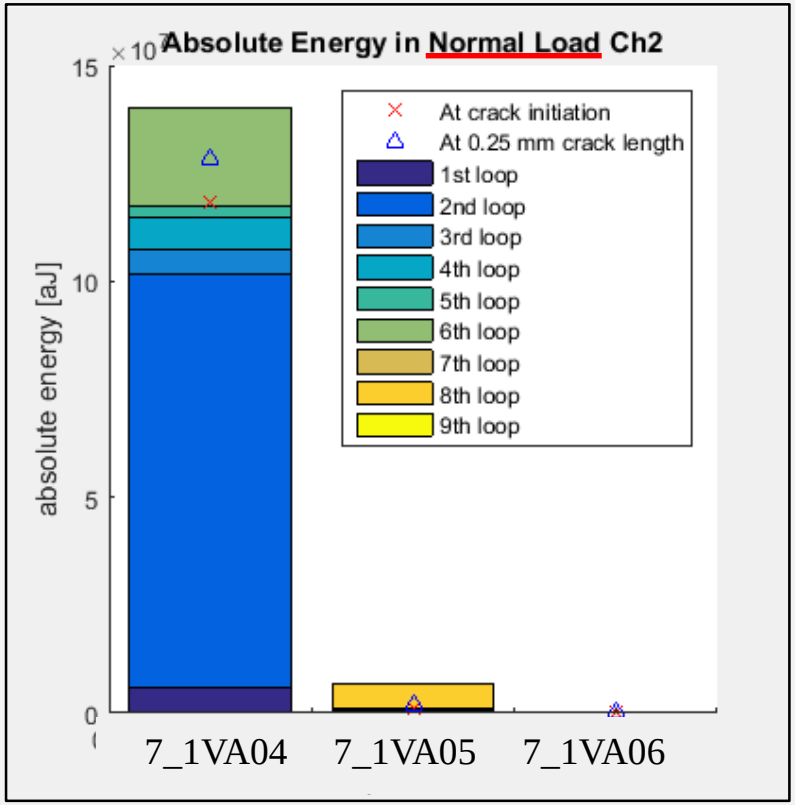
  ☞ This trend is same for all the selected features

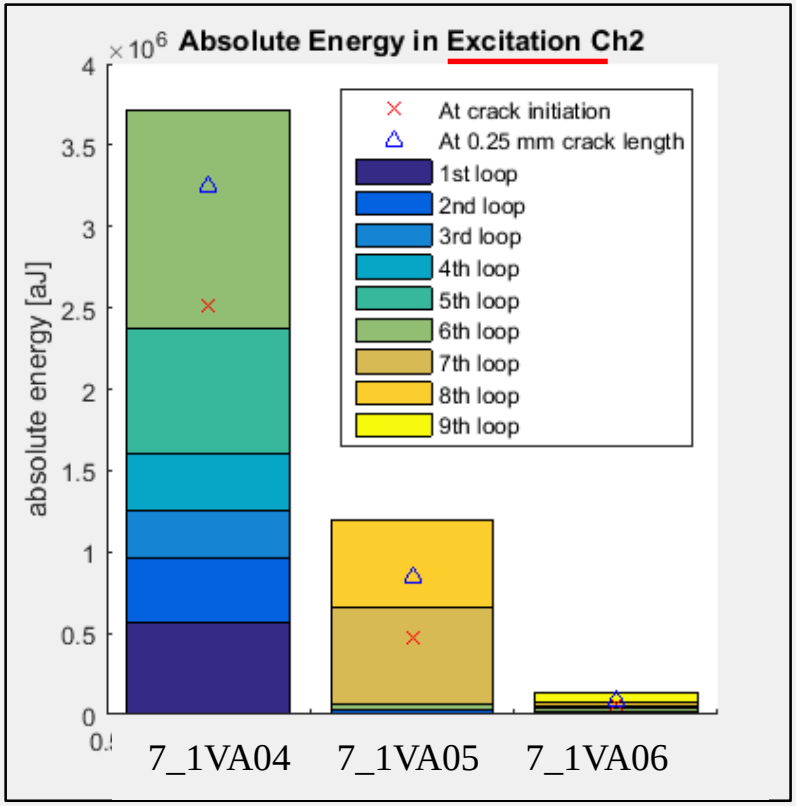




Excitation with AE Features: Fatigue Failure Endurance

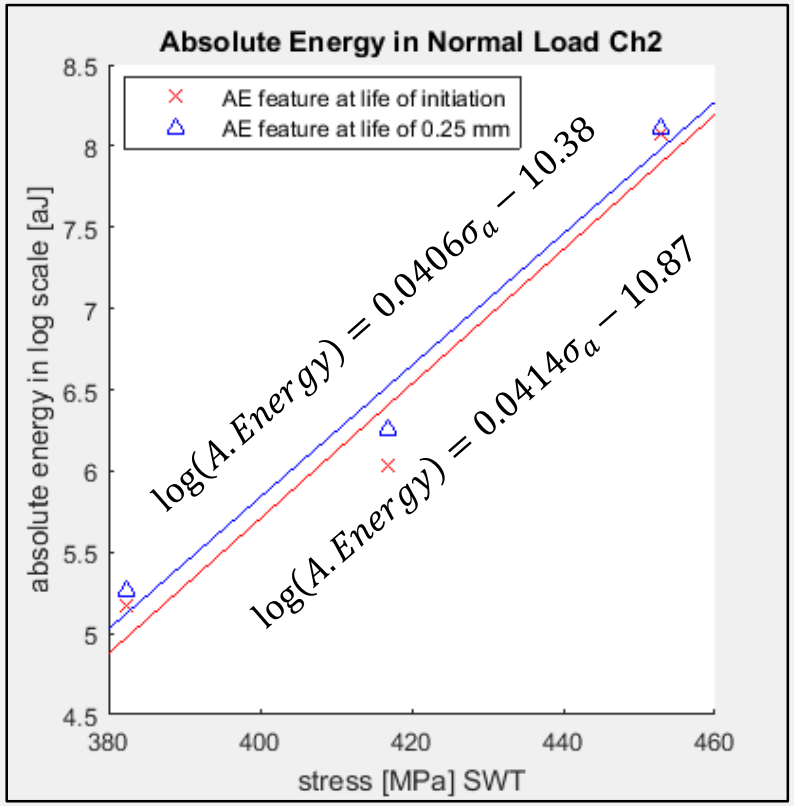
- AE Features summed up to the point of determined fatigue life

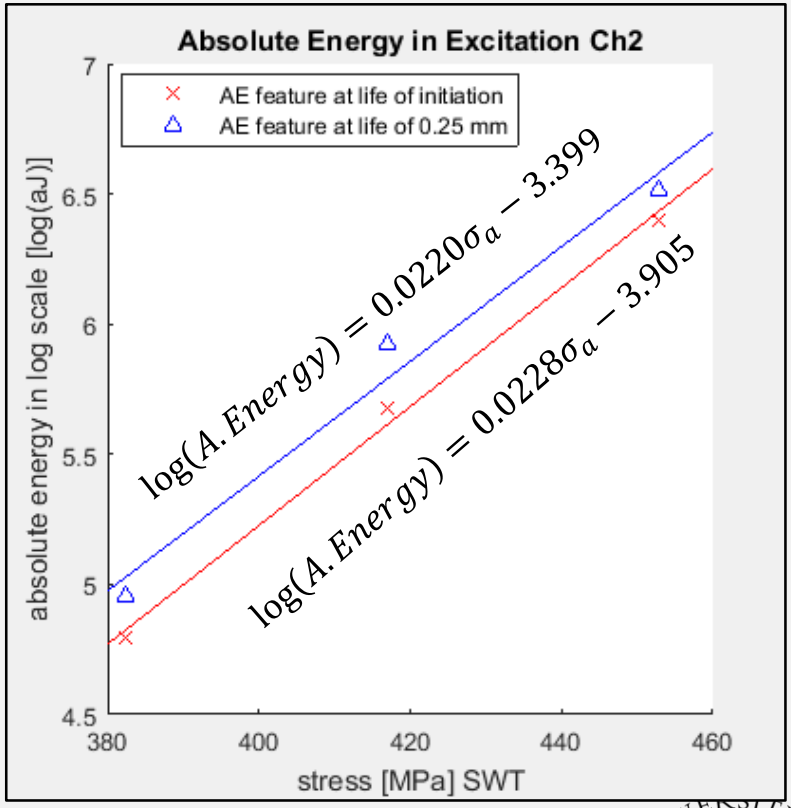




Excitation with AE Features: Load vs. Endurance

- The features versus stress amplitude are correlated





Conclusions

- Two methods for AE signal analyses were investigated:

➢ Information Entropy

- Information entropy of AE waveforms of a series of fatigue tests show close correlate with damage prior to crack initiation and ends at same value when crack initiates

- Information entropy better correlated with damage than the raw AE features

➢ Excitation with AE Features

- AE features collected from excitation has similar pattern as AE features of the actual fatigue loading

- Endurance to fatigue failure is determined with log-linear AE absolute energy

Thank you