# Fatigue measurements on X52 and X70 steels in Hydrogen gas

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Materials Safety Administration

ASME
SETTING THE STANDARD

NIST
National Institute of Standards and Technology

# X52 and X70 Pipeline Steels

**Table 4.1.1. Tensile properties of the 4 steels.**

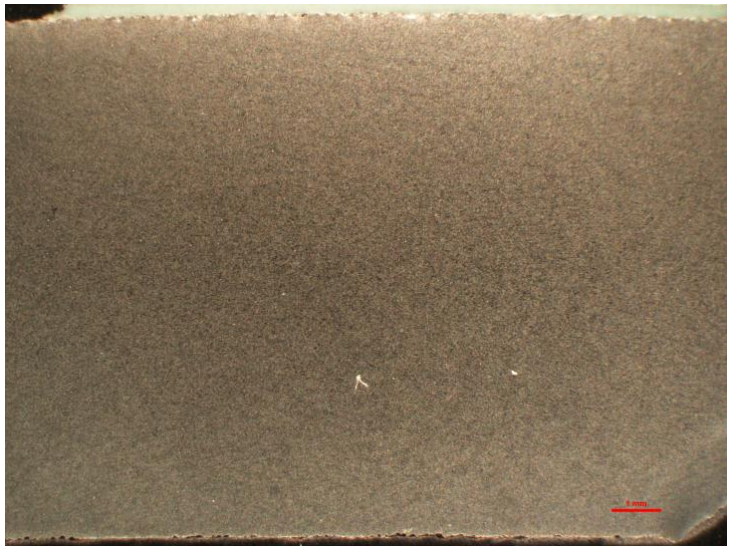
| Steel | $\sigma_y$ [MPa ± std. dev.] | $\sigma_{UTS}$ [MPa ± std. dev.] |
|---|---|---|
| X52_vintage_P (360 MPa) | 325±4 | 526±4 |
| X52_new_AL | 487±5 | 588±5 |
| X70A _C(480 MPa) | 509±19 | 609±4 |
| X70B_EP | 553±18 | 640±9 |

# Chemistries

**Table 4.1.2. Chemistries of two X52 steels and two X70 steels.**
X70A is CRC-Evans (C), X70B is El Paso (EP)

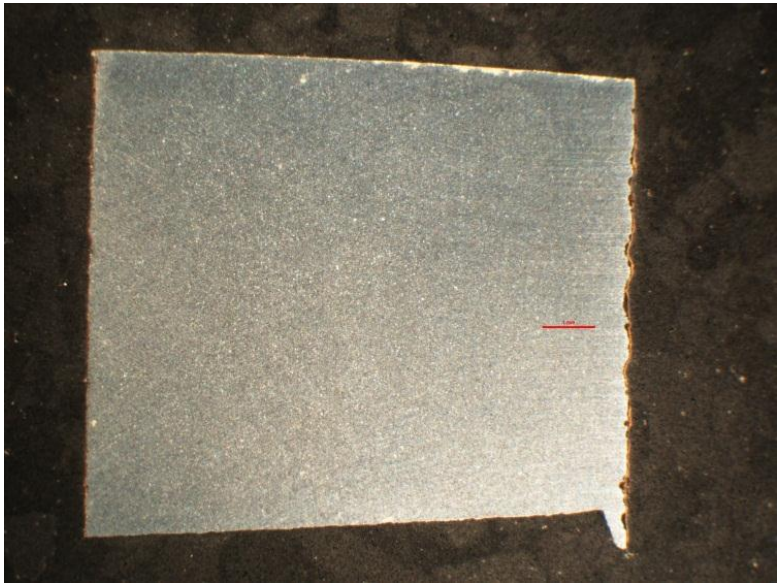
| | Al | B | C | Co | Cr | Cu |
|---|---|---|---|---|---|---|
| X52_old | 0.002 | < 1e-4 | 0.238 | 0.004 | 0.014 | 0.085 |
| X52_new | 0.017 | < 1e-4 | 0.071 | 0.002 | 0.033 | 0.016 |
| X70A | 0.015 | < 1e-4 | 0.048 | 0.002 | 0.240 | 0.220 |
| X70B | 0.012 | < 1e-4 | 0.053 | 0.002 | 0.230 | 0.250 |
| | **Fe** | **H** | **Mn** | **Mo** | **N** | **Nb** |
| X52_old | 98.48 | 0.0001 | 0.96 | 0.004 | 0.003 | 0.001 |
| X52_new | 98.37 | 0.0006 | 1.06 | 0.003 | 0.004 | 0.026 |
| X70A | 97.51 | 0.0003 | 1.43 | 0.005 | 0.005 | 0.054 |
| X70B | 97.41 | 0.0009 | 1.53 | 0.003 | 0.005 | 0.054 |
| | **Ni** | **P** | **S** | **Si** | **Ti** | **V** |
| X52_old | 0.05 | 0.011 | 0.021 | 0.064 | 0.002 | 0.002 |
| X52_new | 0.016 | 0.012 | 0.004 | 0.24 | 0.038 | 0.004 |
| X70A | 0.014 | 0.009 | 0.001 | 0.17 | 0.027 | 0.004 |
| X70B | 0.014 | 0.01 | 0.001 | 0.16 | 0.024 | 0.004 |

# X52 Low Magnification

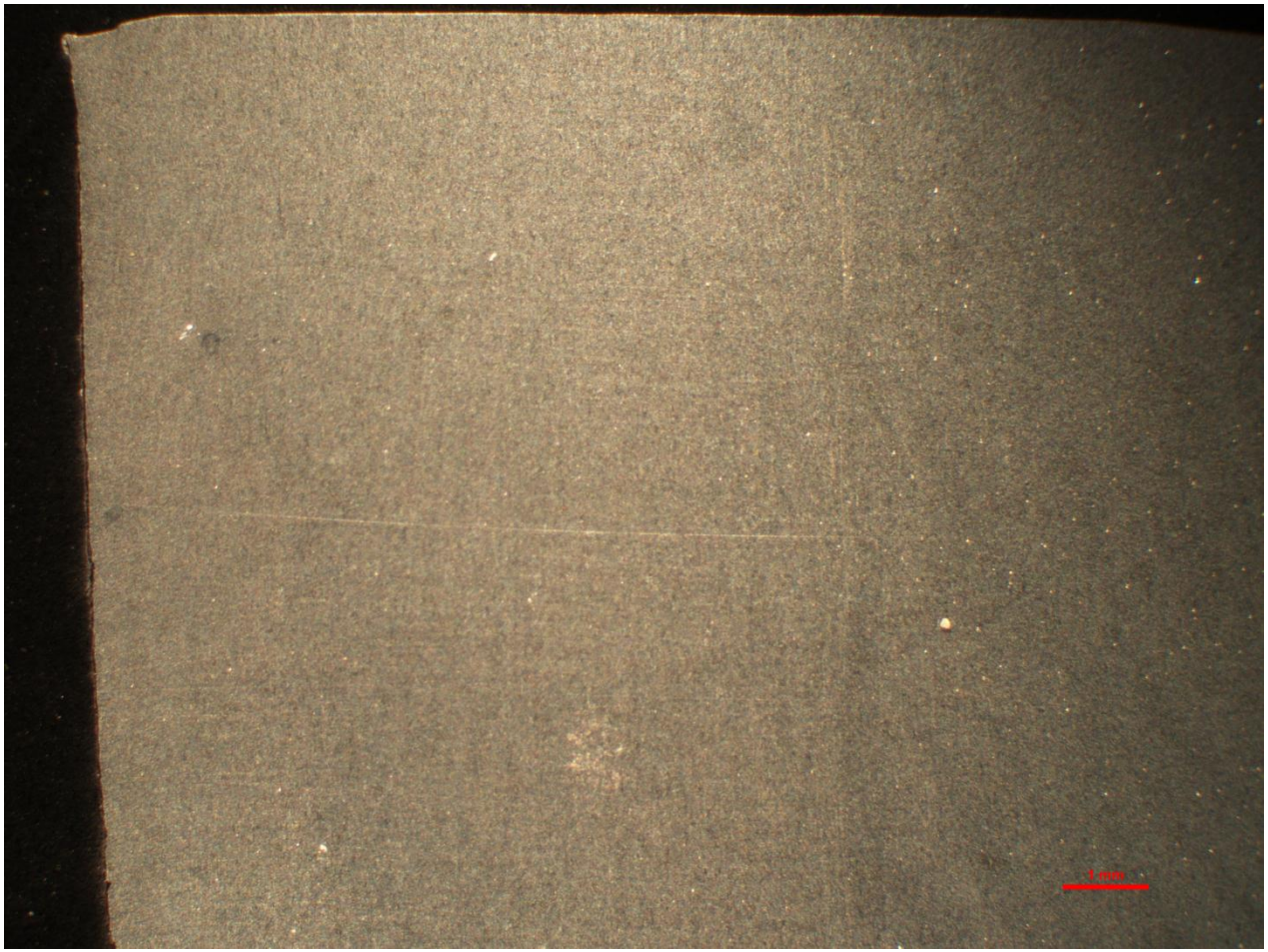


X52 Old (P) , scale bar = 1 mm

X52 New (AL), scale bar 1 mm

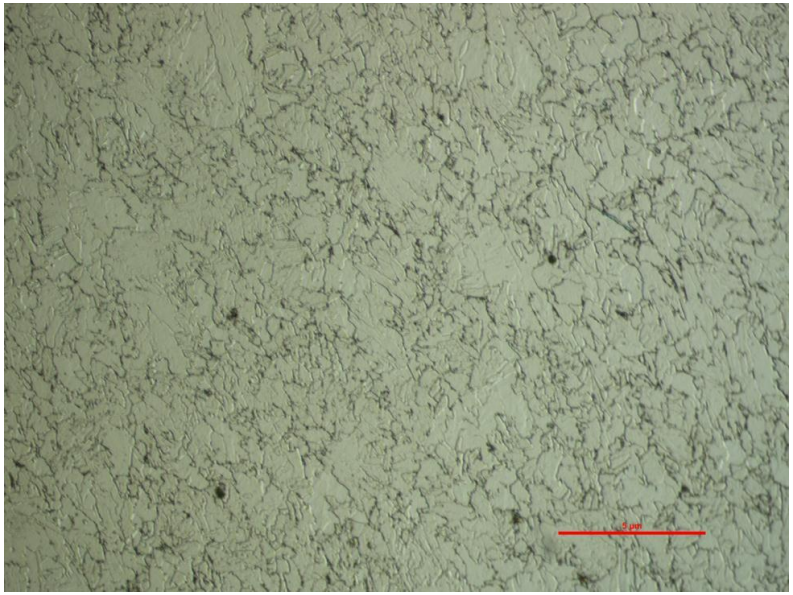


# Low Magnification Image of X70A (C)



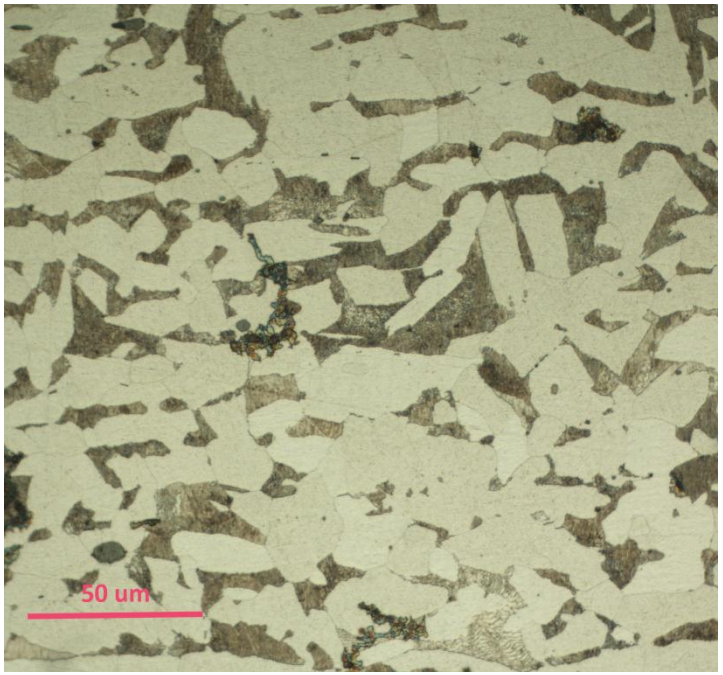

X70 A (CRC-Evans), scale bar = 1 mm

# X52 Microstructures

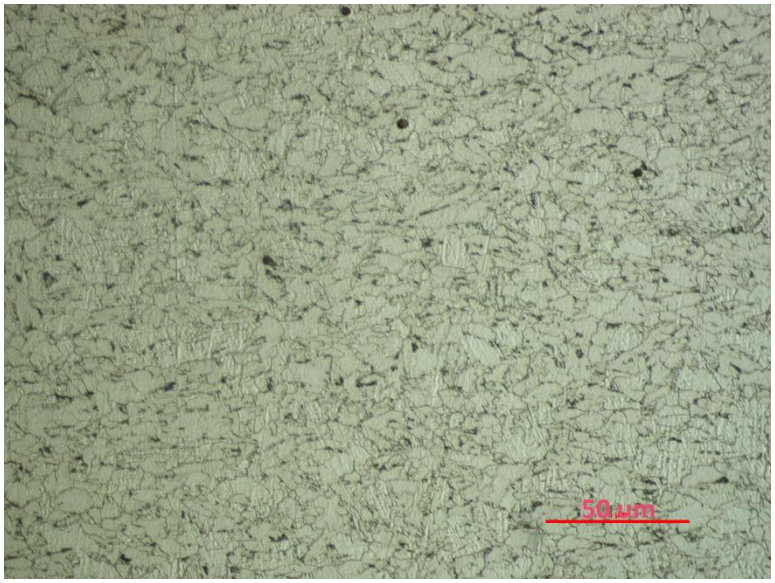


X52 New (AL), scale bar is 50 µm
20 in dia. Pipe, 10.6 mm wall thickness
Polygonal ferrite (light), acicular ferrite and dispersed carbides (dark spots)

X52 Old (P), scale bar is 50 µm
36 in dia. Pipe, 10.6 mm wall thickness
70 % Polygonal ferrite (light), and 30 % pearlite (dark)

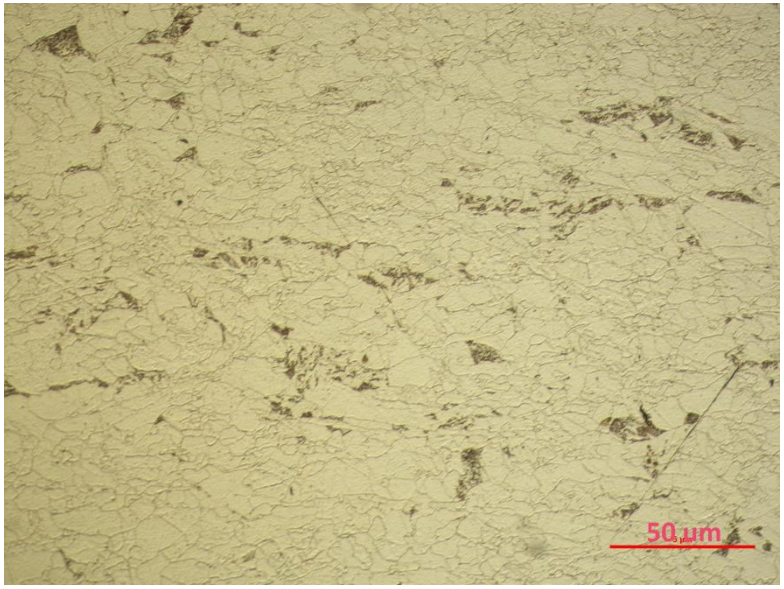


# X70 Microstructures

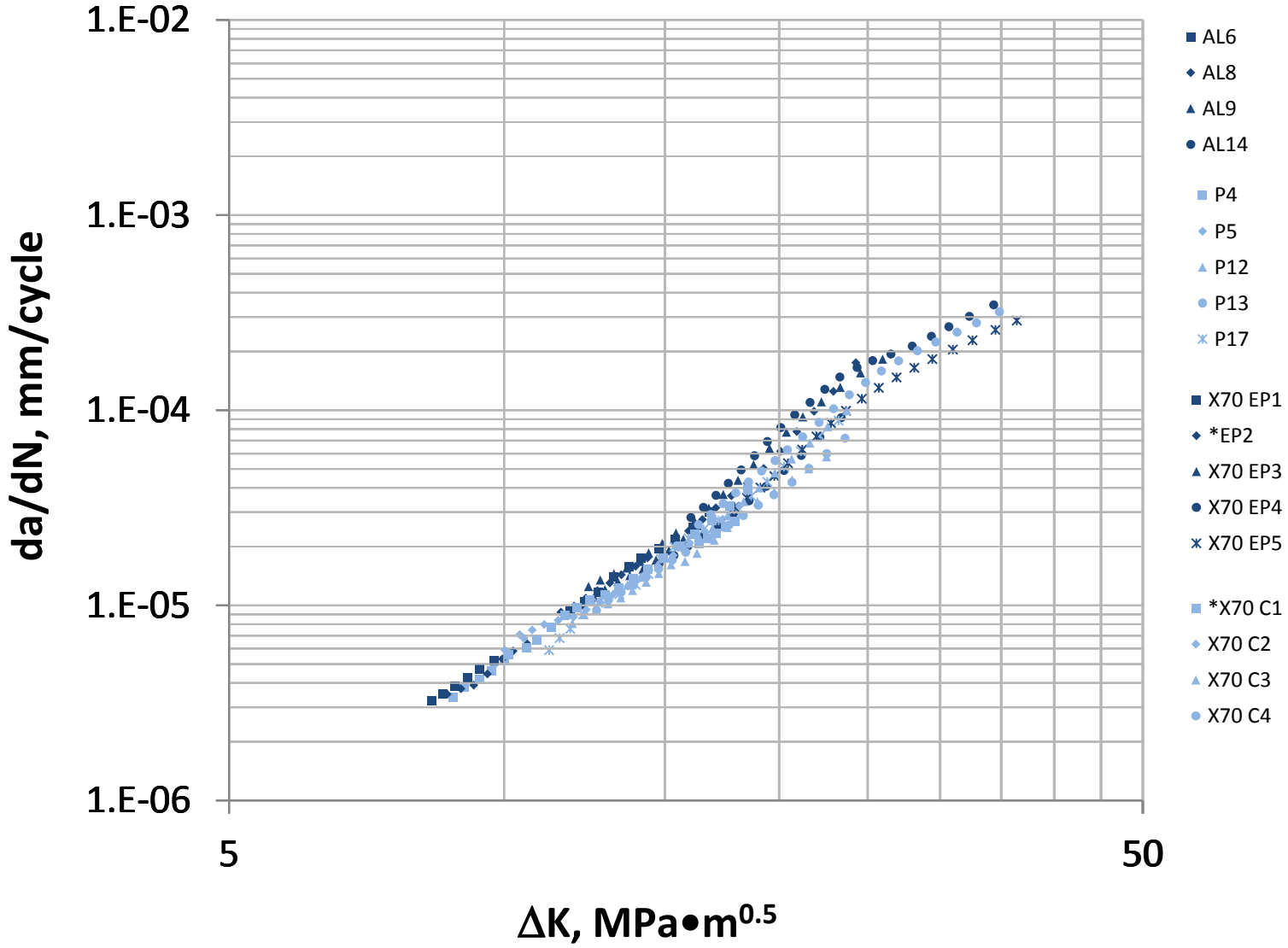



X70 A (C), scale bar is 50 µm
36 in dia. Pipe, 18 mm wall thickness
93 – 94 % Polygonal ferrite (light), ~5% acicular ferrite and 1 – 2 % pearlite (dark spots)

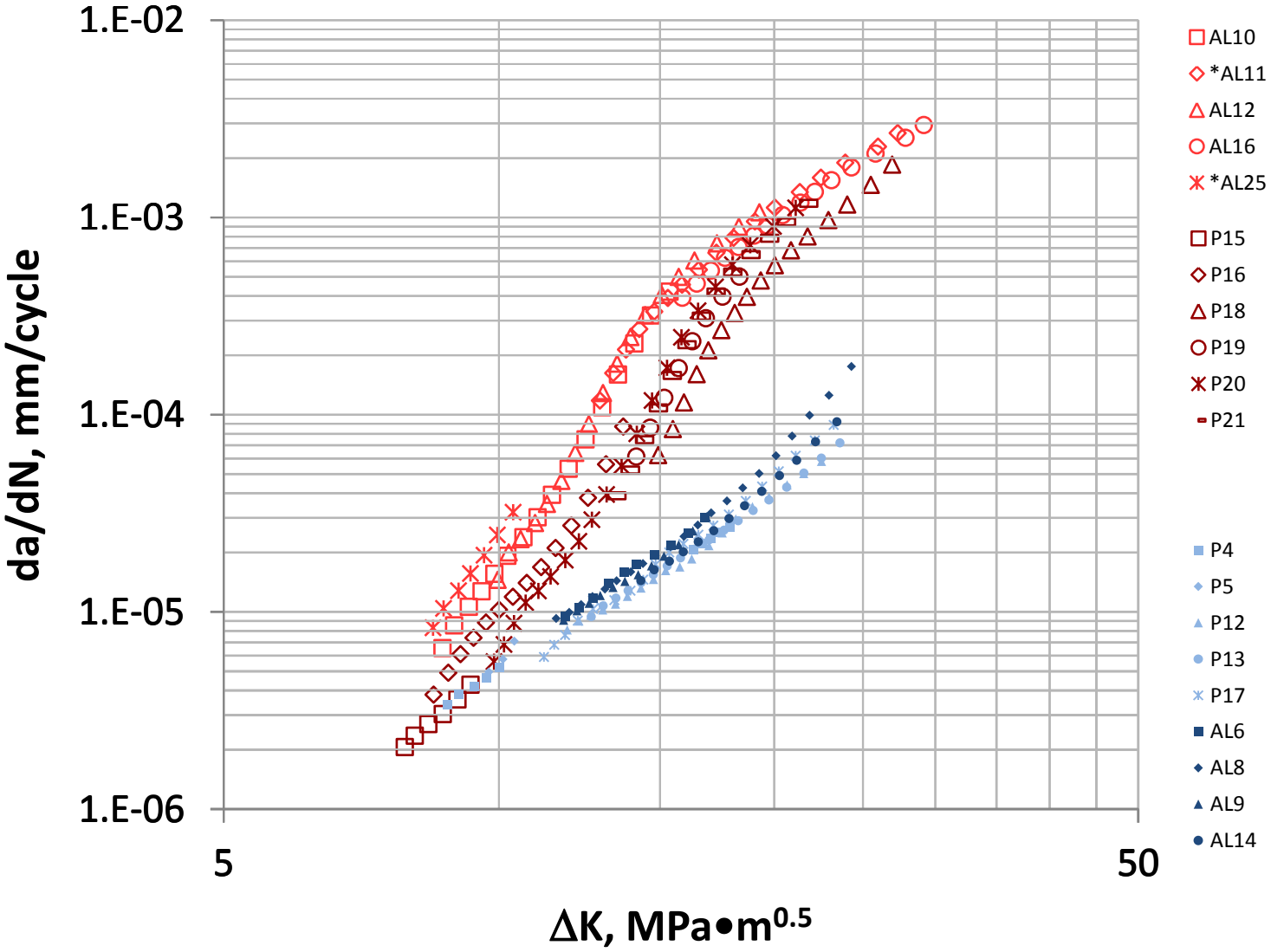
X70 B(EP), scale bar is 50 µm
36 in dia. Pipe, 22 mm wall thickness
95 – 96 % Polygonal ferrite (light) and 4 – 5 % upper bainite (dark),



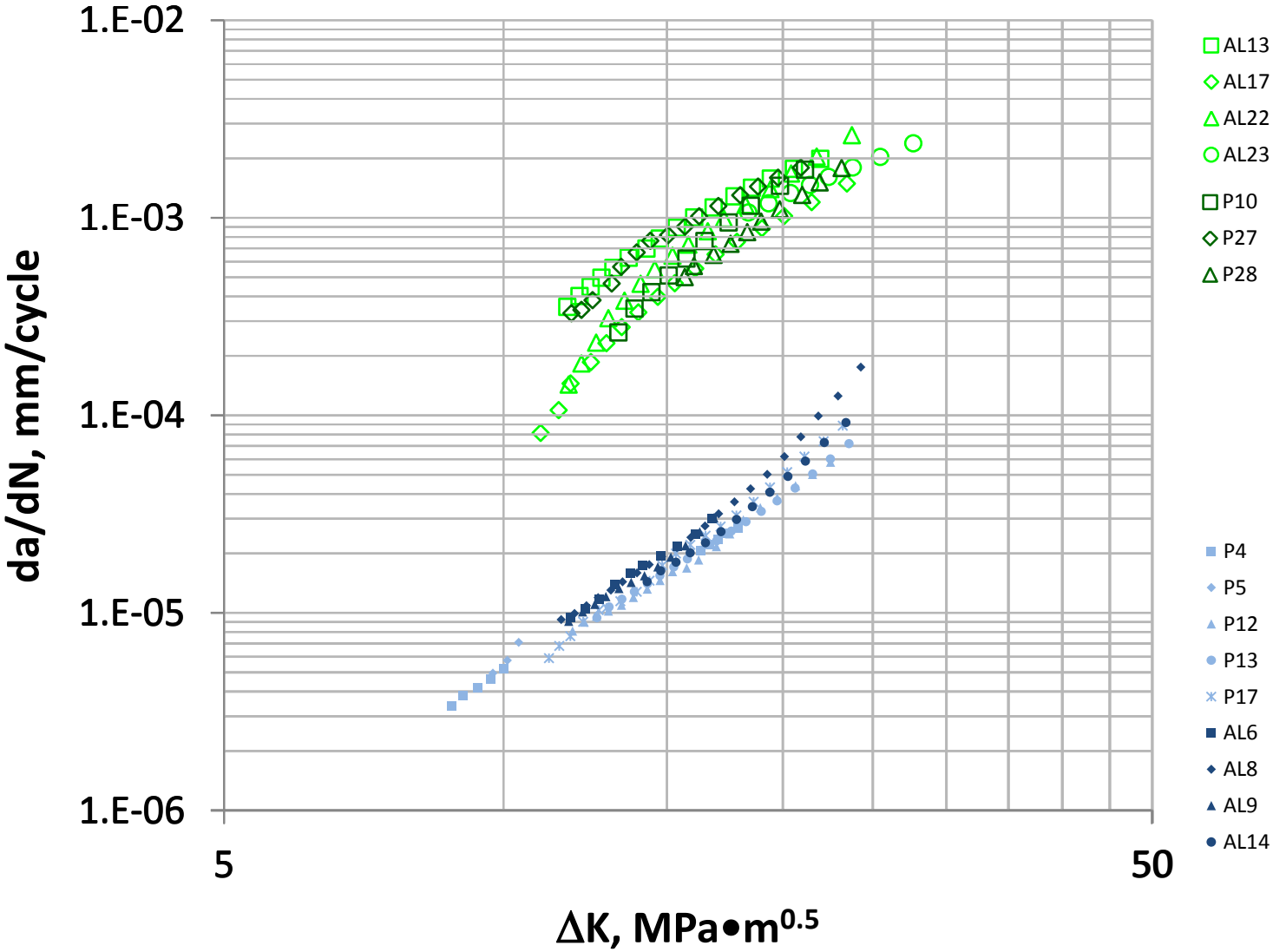
# X52 and X70 Air Data



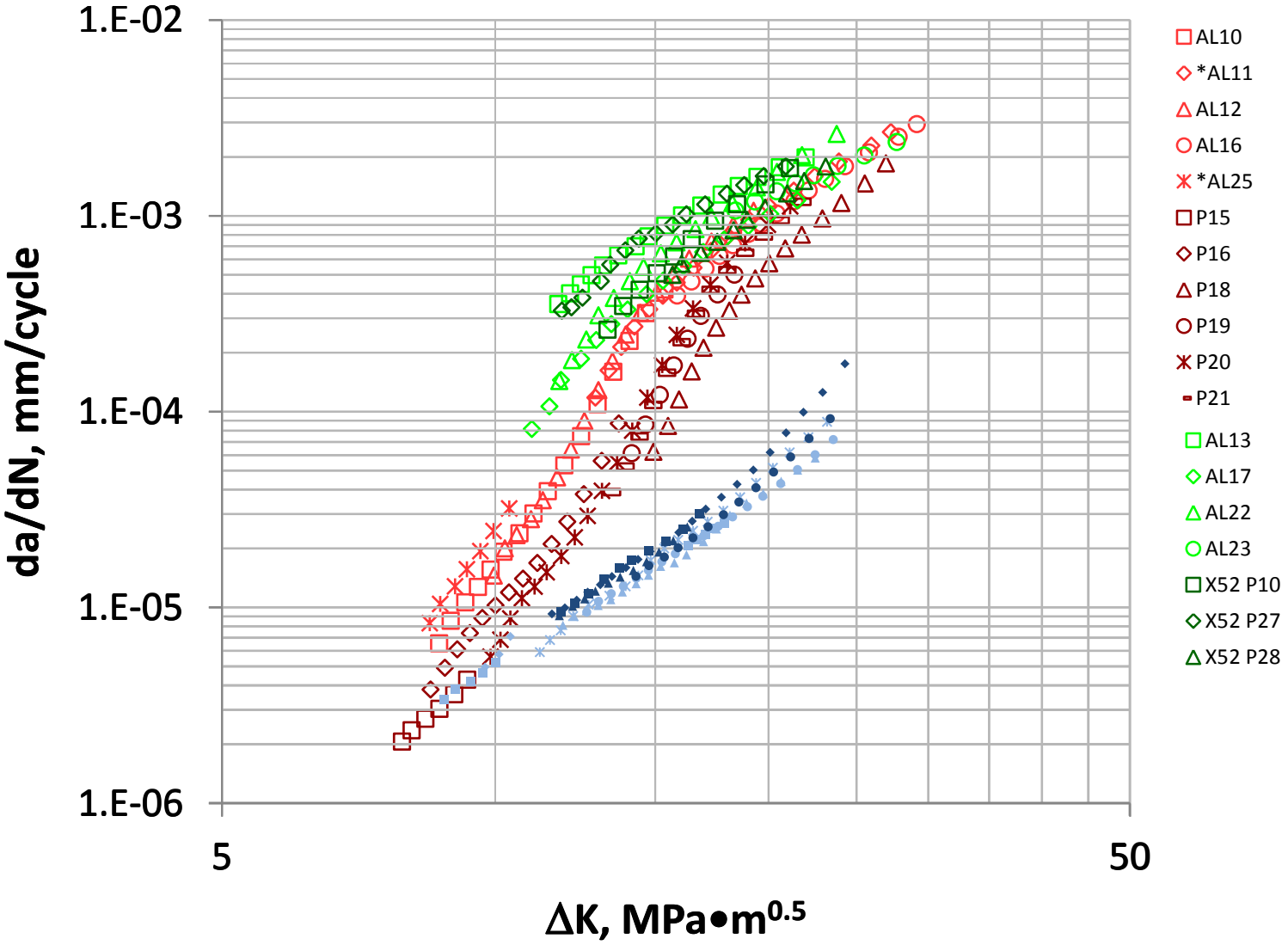
# X52 5.5 MPa (800 psi), 1 Hz hydrogen and air



# X52 34 MPa (5000 psi), 1 Hz hydrogen and air

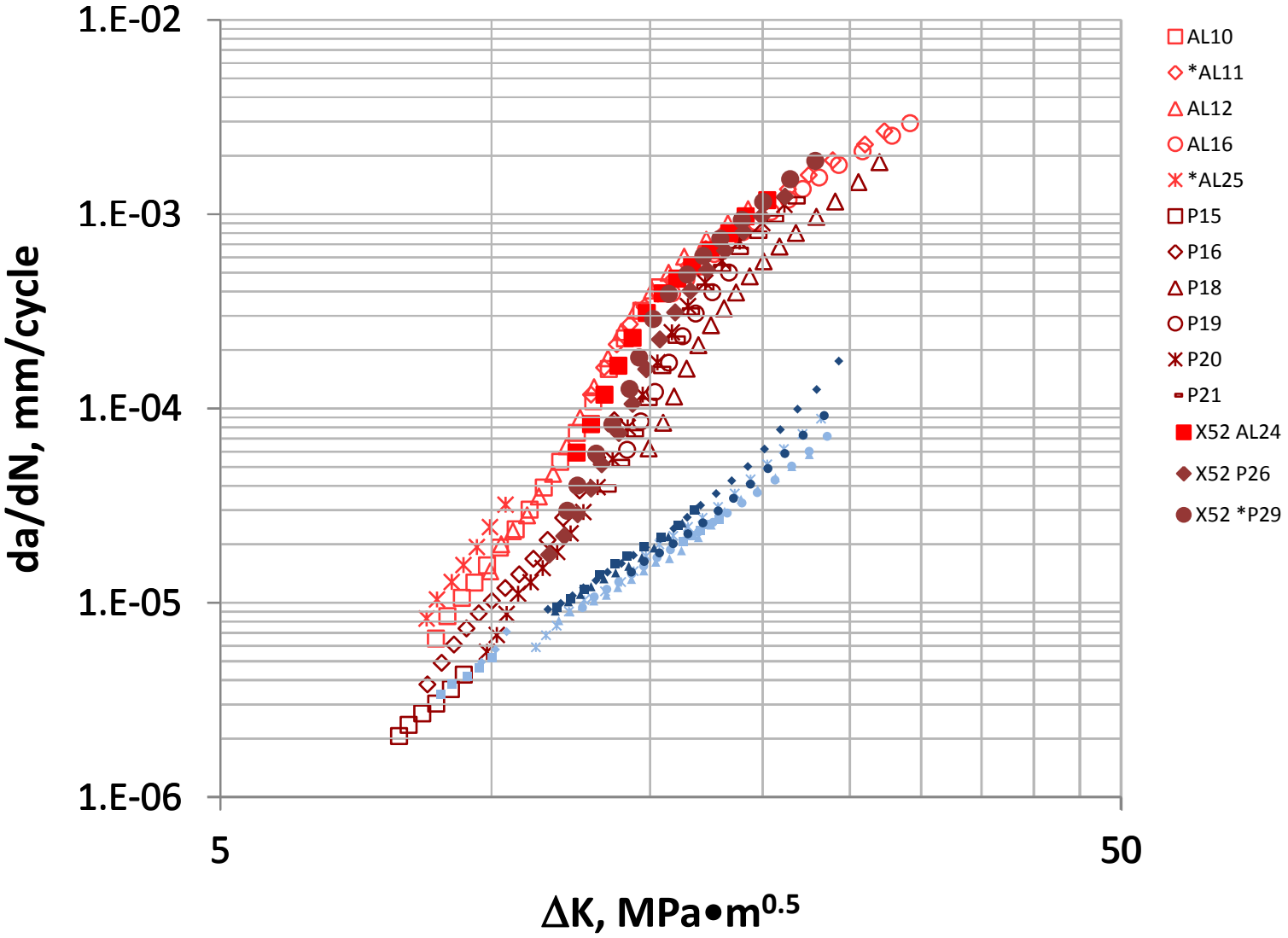


# X52, 1 Hz: 5.5 (red) & 34 MPa (green) hydrogen and air (blue)



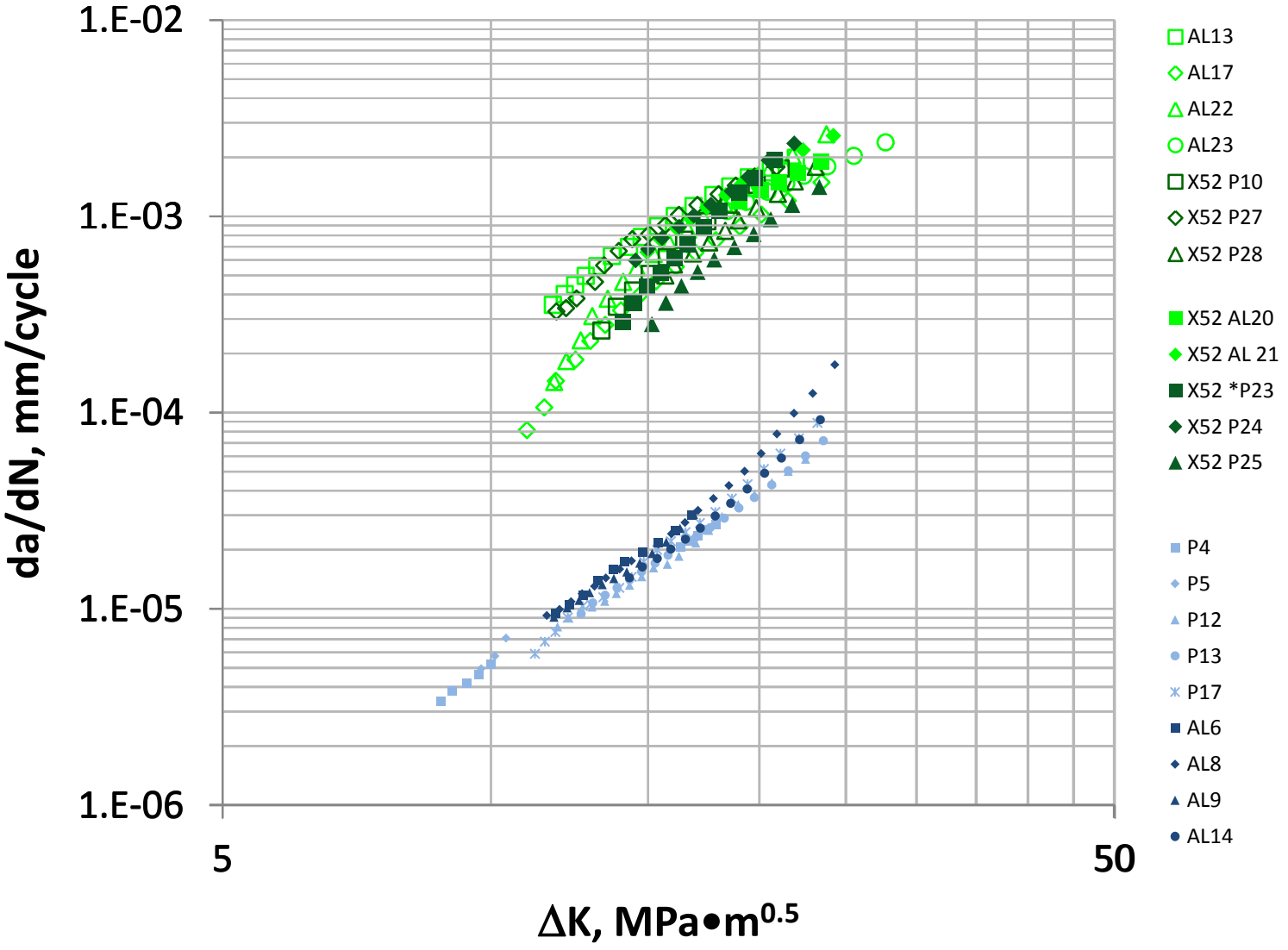
# X52 5.5 MPa (800 psi), 0.1 Hz and 1 Hz hydrogen

Open symbols, 1 Hz; closed symbols 0.1 Hz, small blue symbols, air

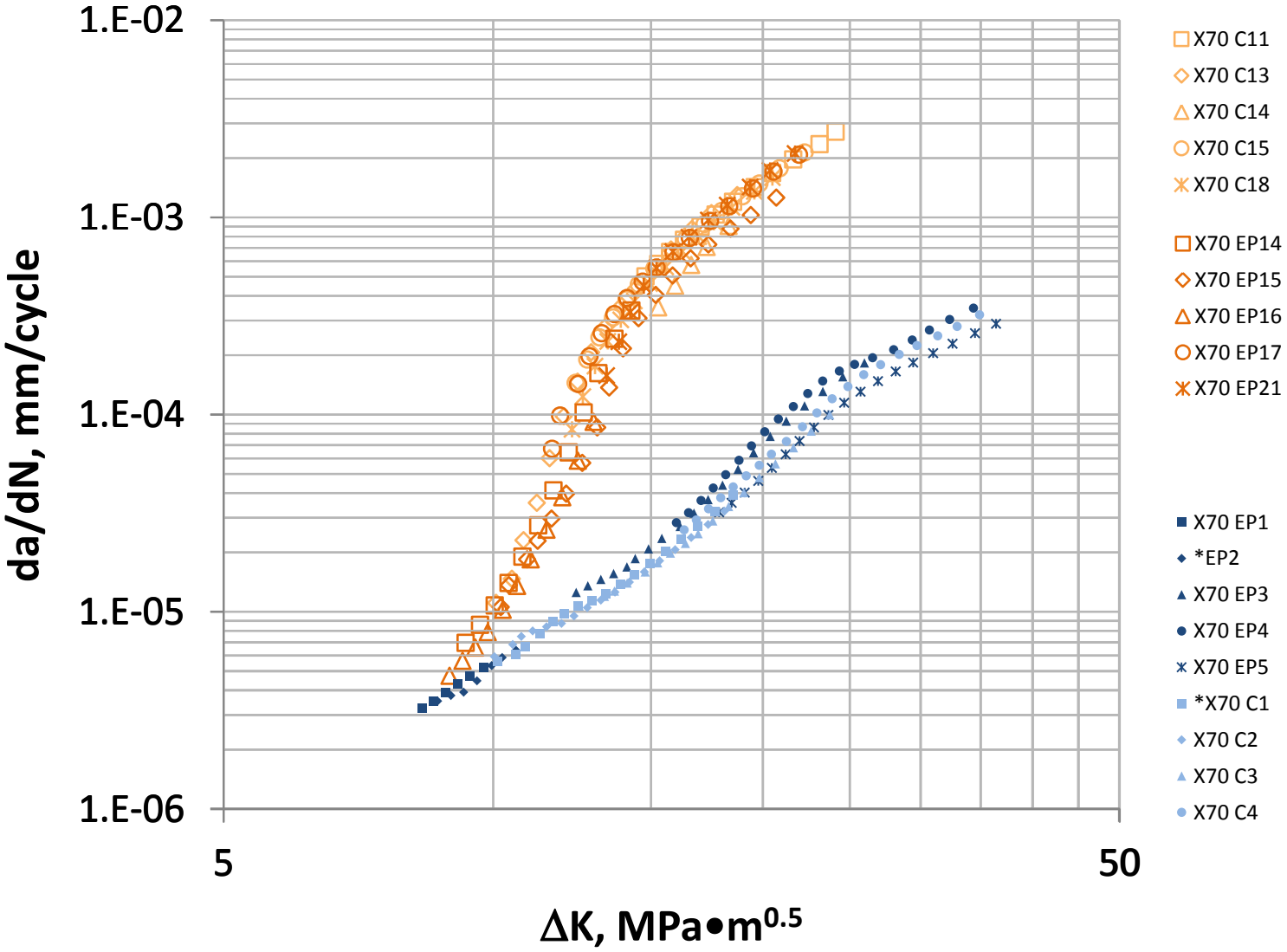


# X52 34 MPa (5000 psi), 1 Hz and 0.1 Hz hydrogen

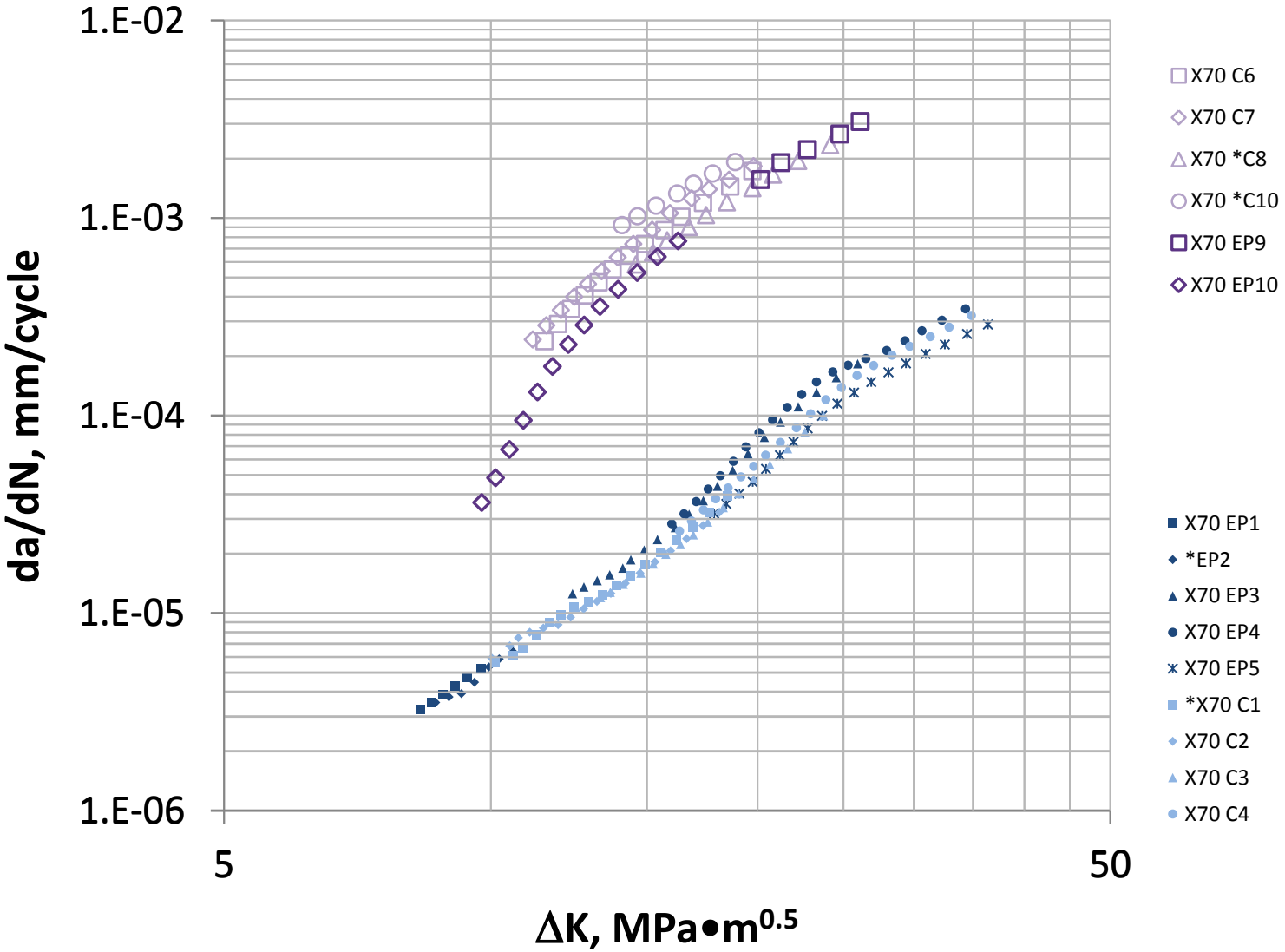
Open symbols, 1 Hz; closed symbols 0.1 Hz, small blue symbols, air



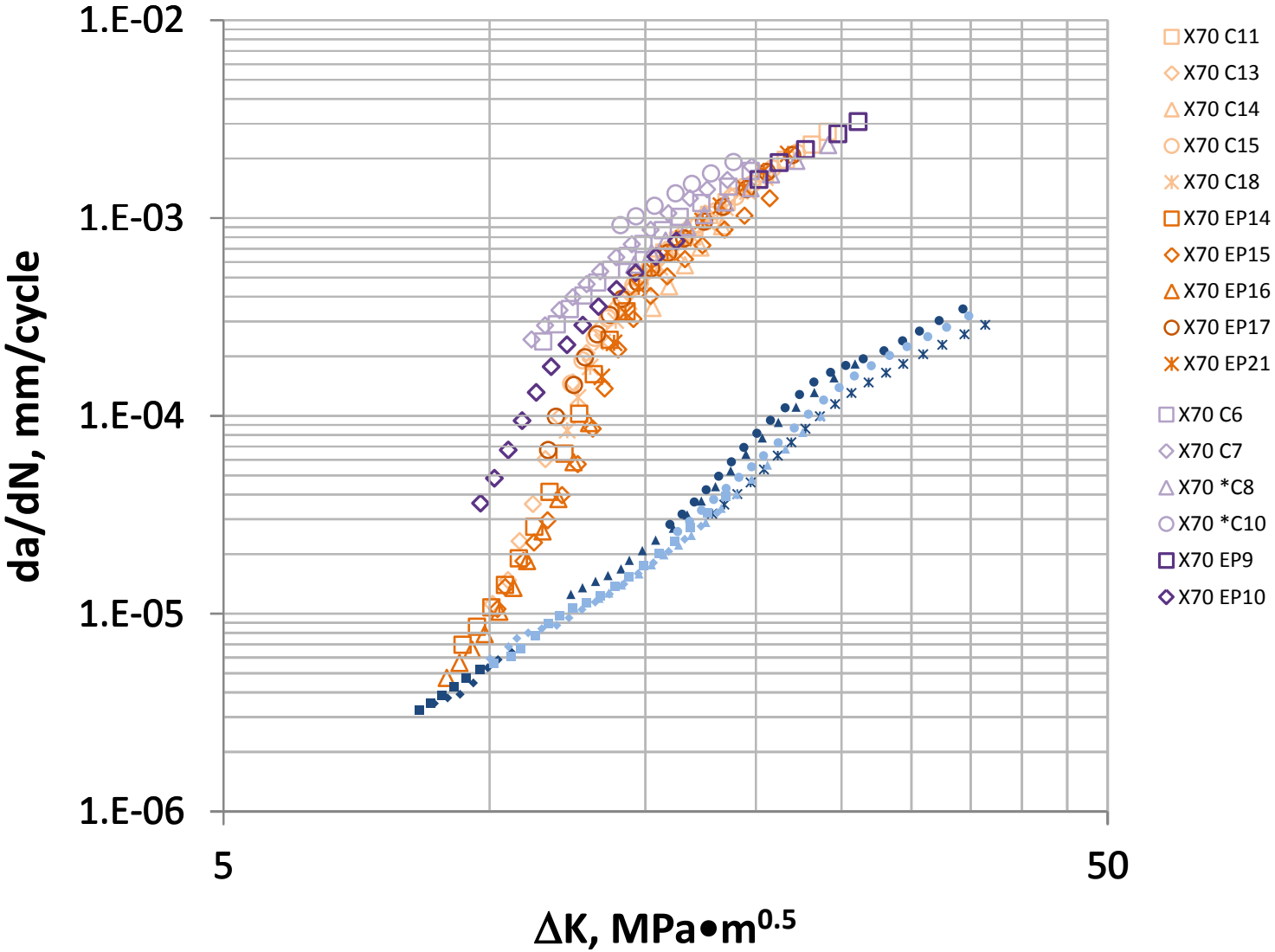
# X70 5.5 MPa (800 psi), 1 Hz hydrogen and air



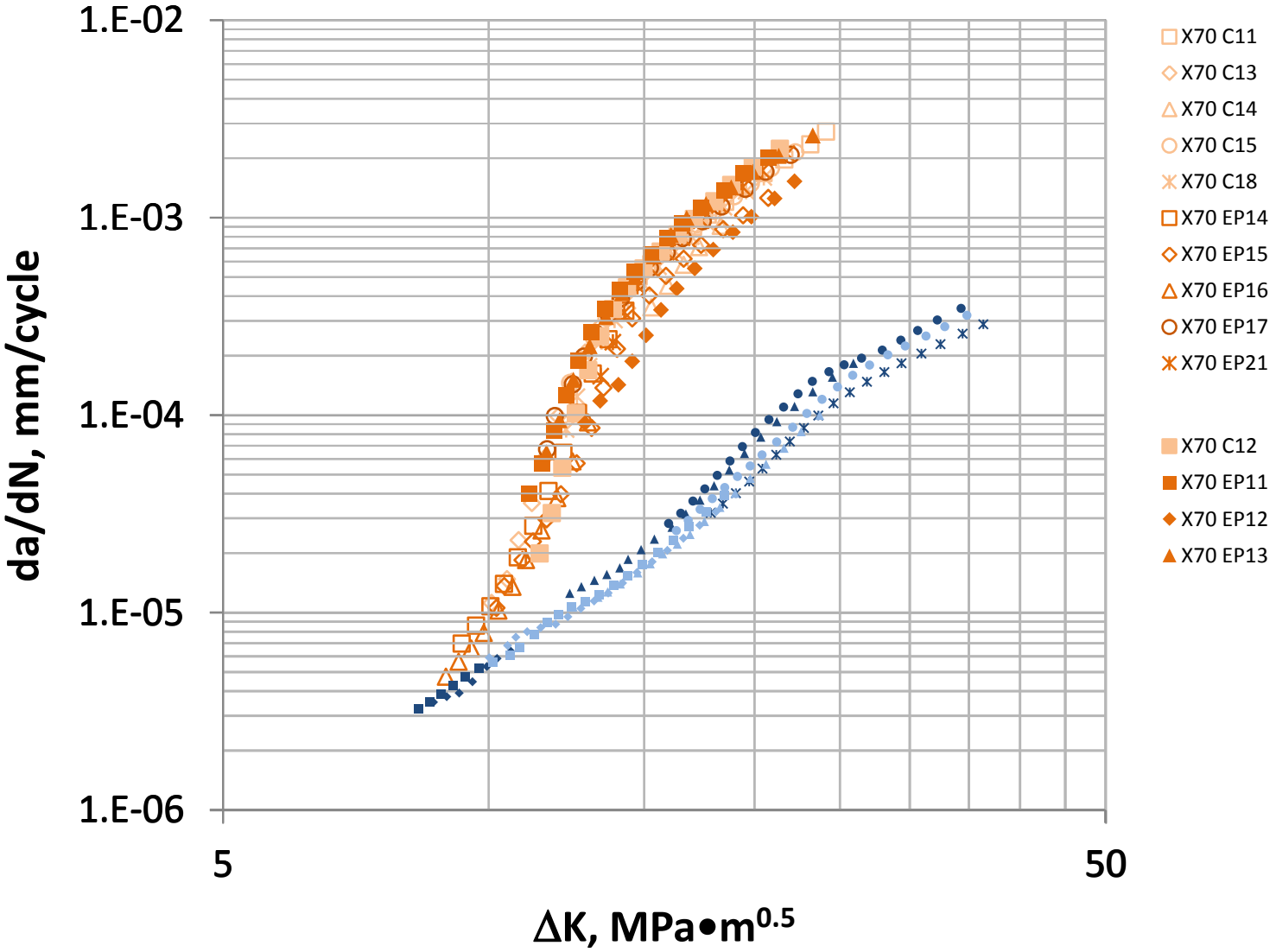
# X70 34 MPa (5000 psi), 1 Hz hydrogen and air



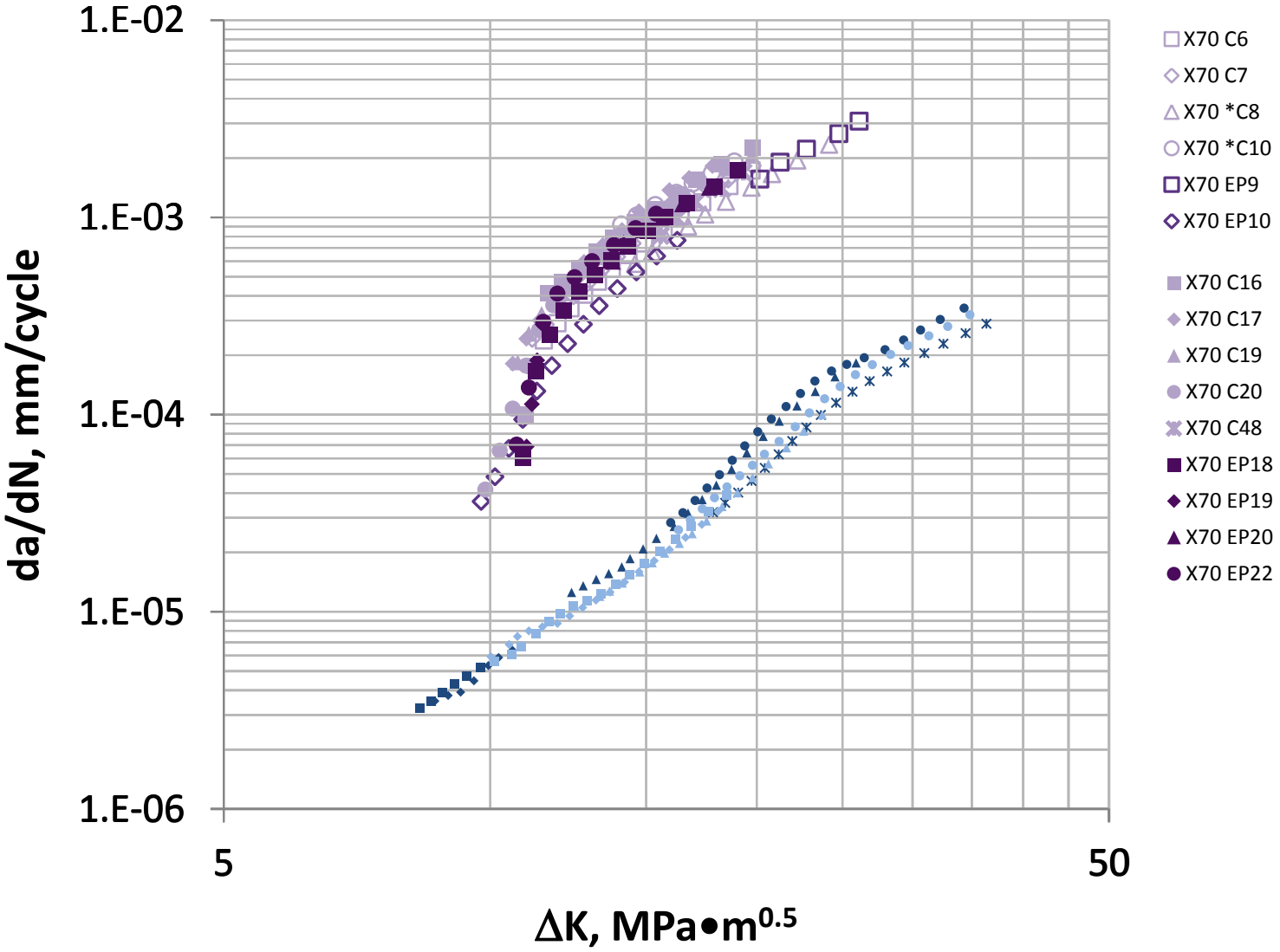
# X70, 1 Hz: 5.5 (orange) & 34 MPa (purple) hydrogen and air (blue)



# X70 5.5 MPa (800 psi), 0.1 Hz and 1 Hz hydrogen

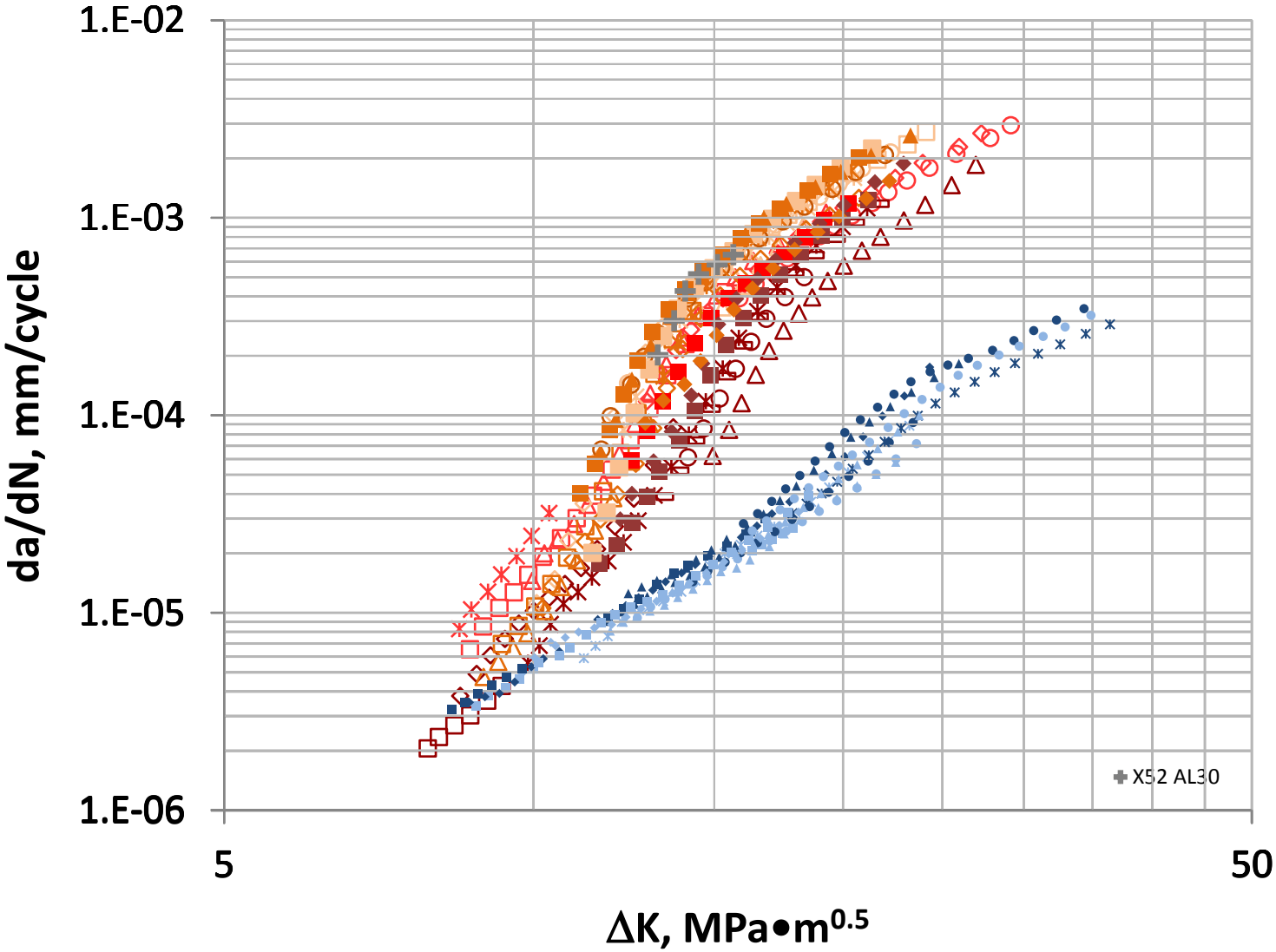


# X70 34 MPa (5000 psi), 1 Hz and 0.1 Hz hydrogen



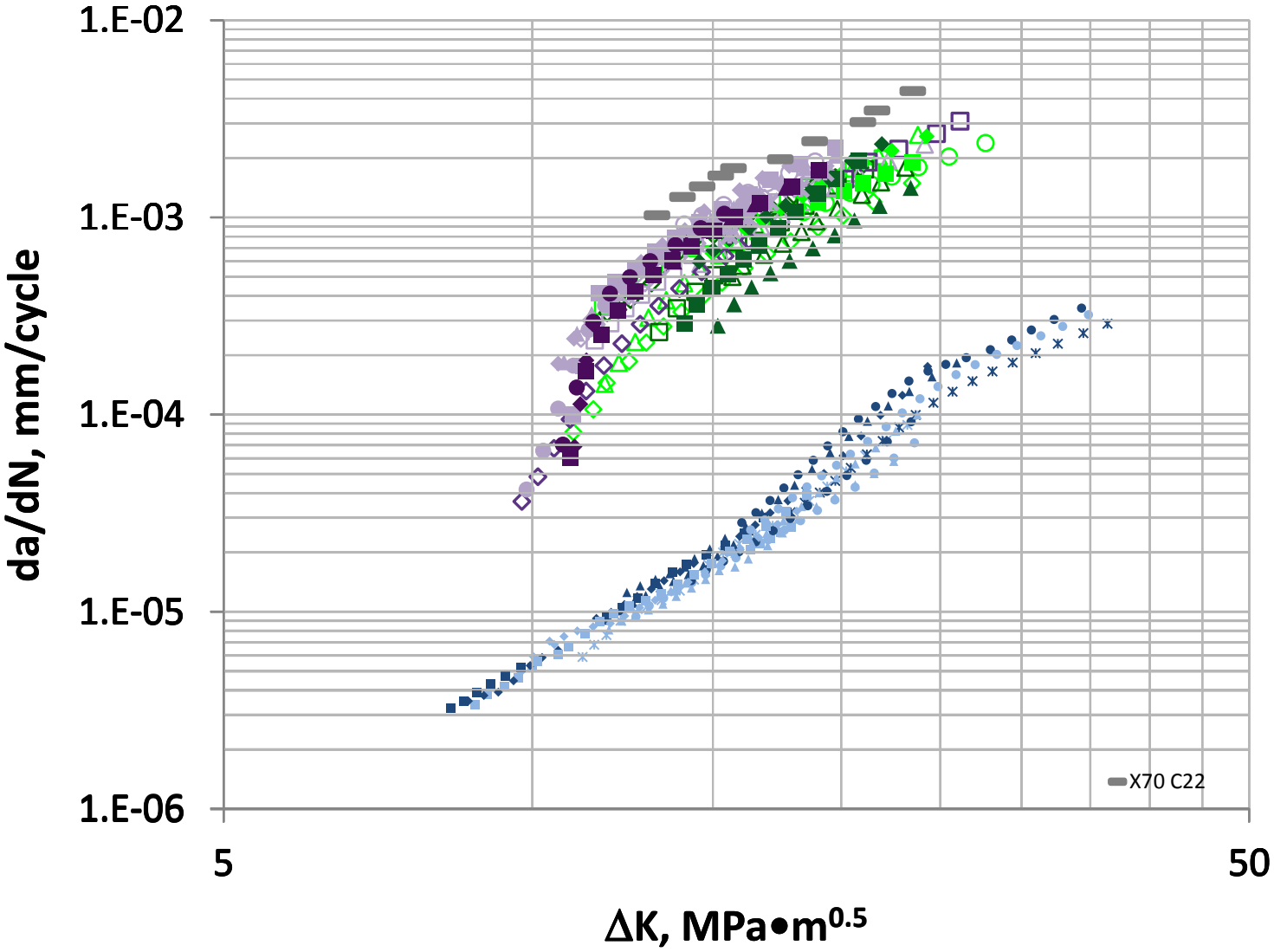
# X52 and X70 5.5 MPa (800 psi) hydrogen and air

OPEN 1 Hz: Light red, X52 AL; dark red, X52 P; light orange, X70 C; dark orange, X70 EP
CLOSED 0.1 Hz: light red,X52 AL; dark red,  X52 P; light orange, X70 C; dark orange, X70 EP
Blues are air of both steels; Grey (plus), X52 AL, 0.001 Hz, preliminary

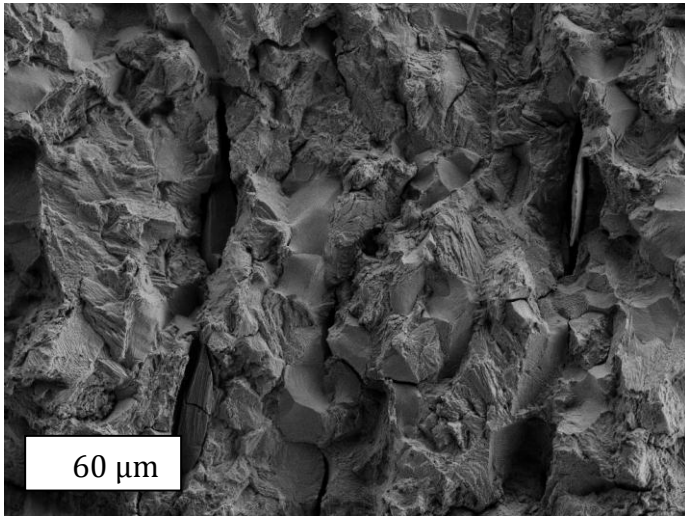


# X52 and X70, 34 MPa (5000 psi) hydrogen and air

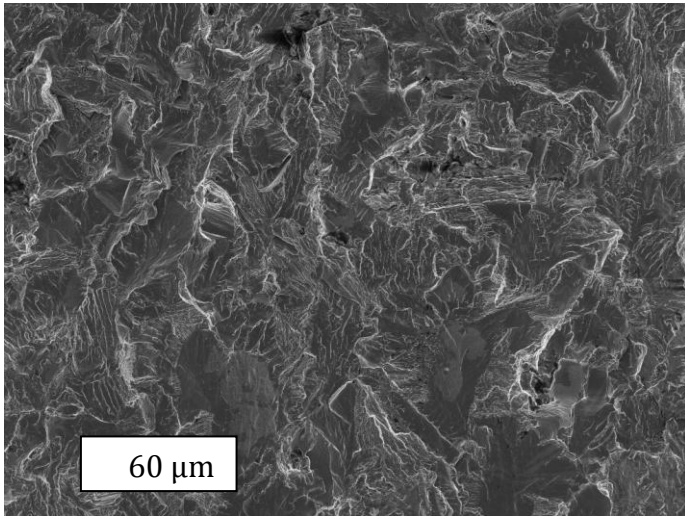
OPEN 1 Hz: Light green, X52 AL; Dark green, X52 P; Light purple, X70 C; Dark purple, X70 EP
CLOSED 0.1 Hz: Light green, X52 AL; Dark green, X52 P; Light purple, X70 C; Dark purple, X70 EP
Blues are air of both steels; Grey (minus), X70 C 0.001Hz, preliminary



# Fractography of X52 Old

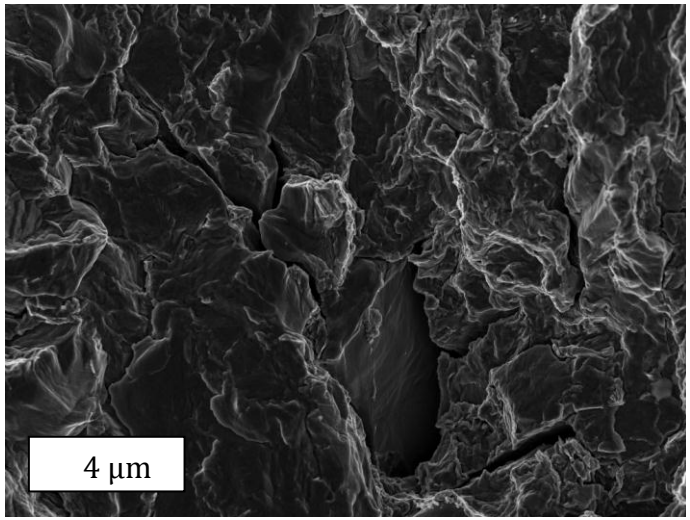



*Intergranular fracture morphology for the old X52 steel at low ΔK, 5.5 Mpa hydrogen, 1 Hz, R=0.5.*

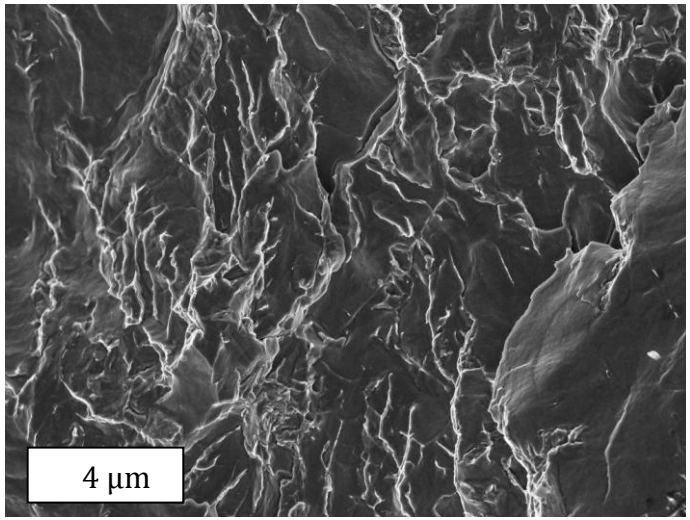



*Transgranular fracture morphology for the old X52 steel at low ΔK, 5.5 Mpa hydrogen, 1 Hz, R=0.5.*

# Fractography of X70A



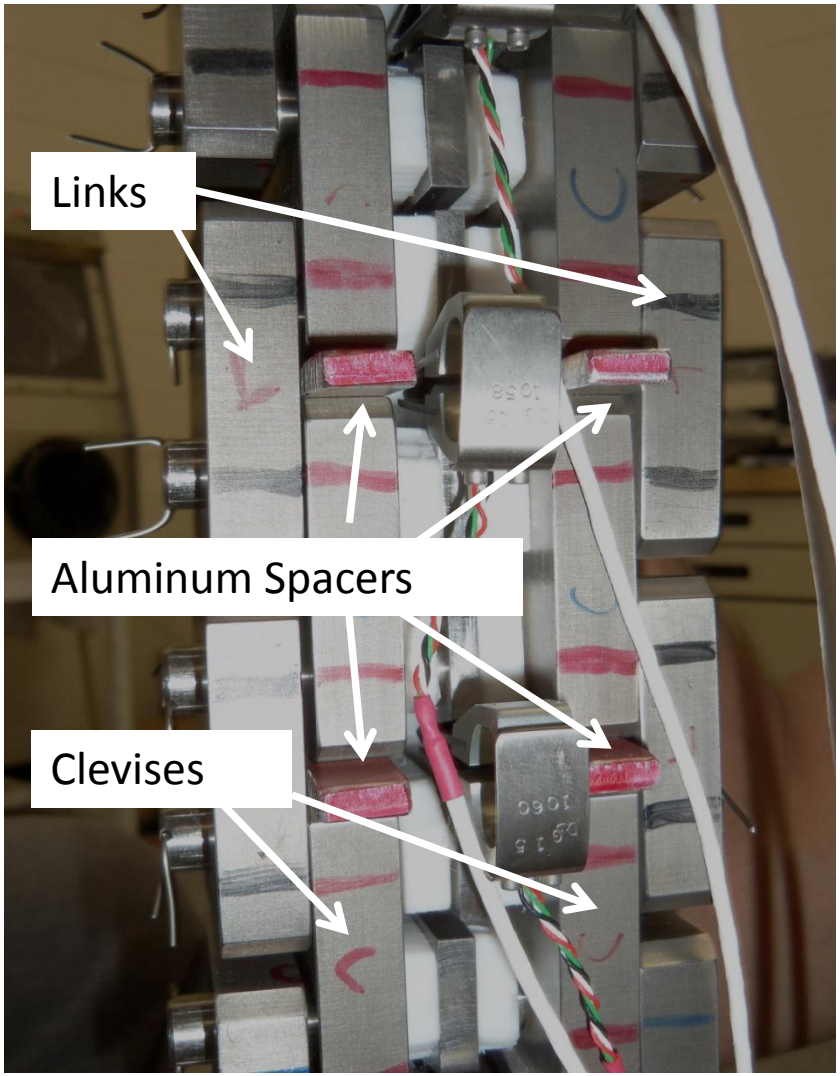

*Intergranular fracture morphology for X70A steel at low ΔK, 5.5 Mpa hydrogen, 1 Hz, R=0.5.*



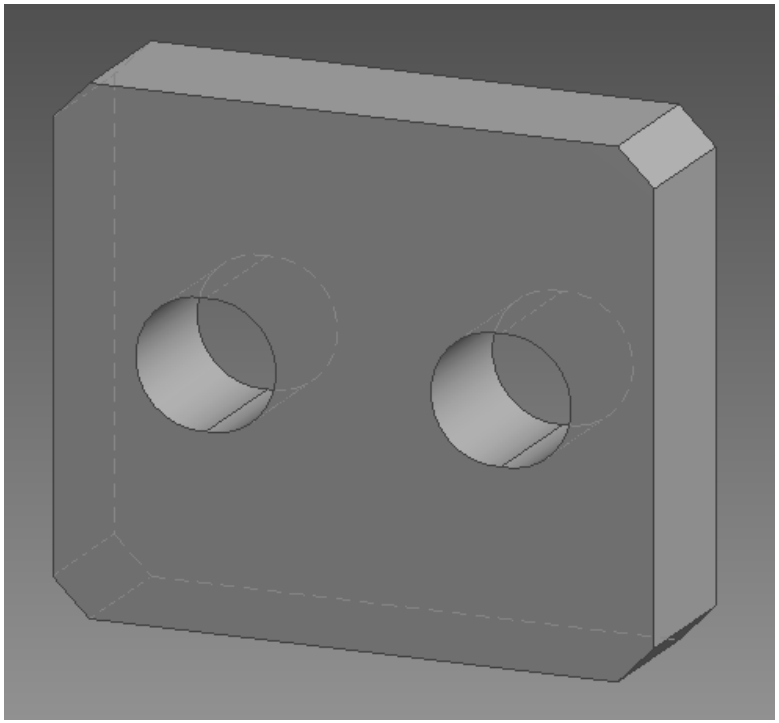

*Transgranular fracture morphology for X70A steel at high ΔK, 5.5Mpa hydrogen, 1 Hz, R=0.5.*

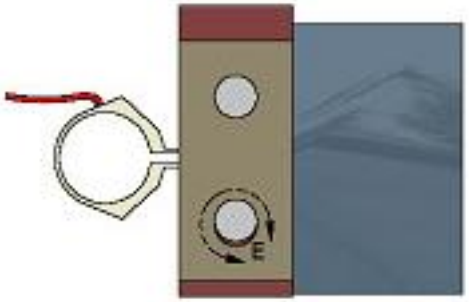
# Multiple-Specimen Testing in Hydrogen

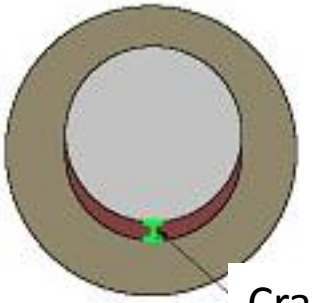
- Simultaneously test 10 C(T) specimens
- Constant load amplitude
- Test continues until all 10 specimens crack to 0.7 *W*
- ASTM E647



# Multiple-Specimen Testing in Hydrogen





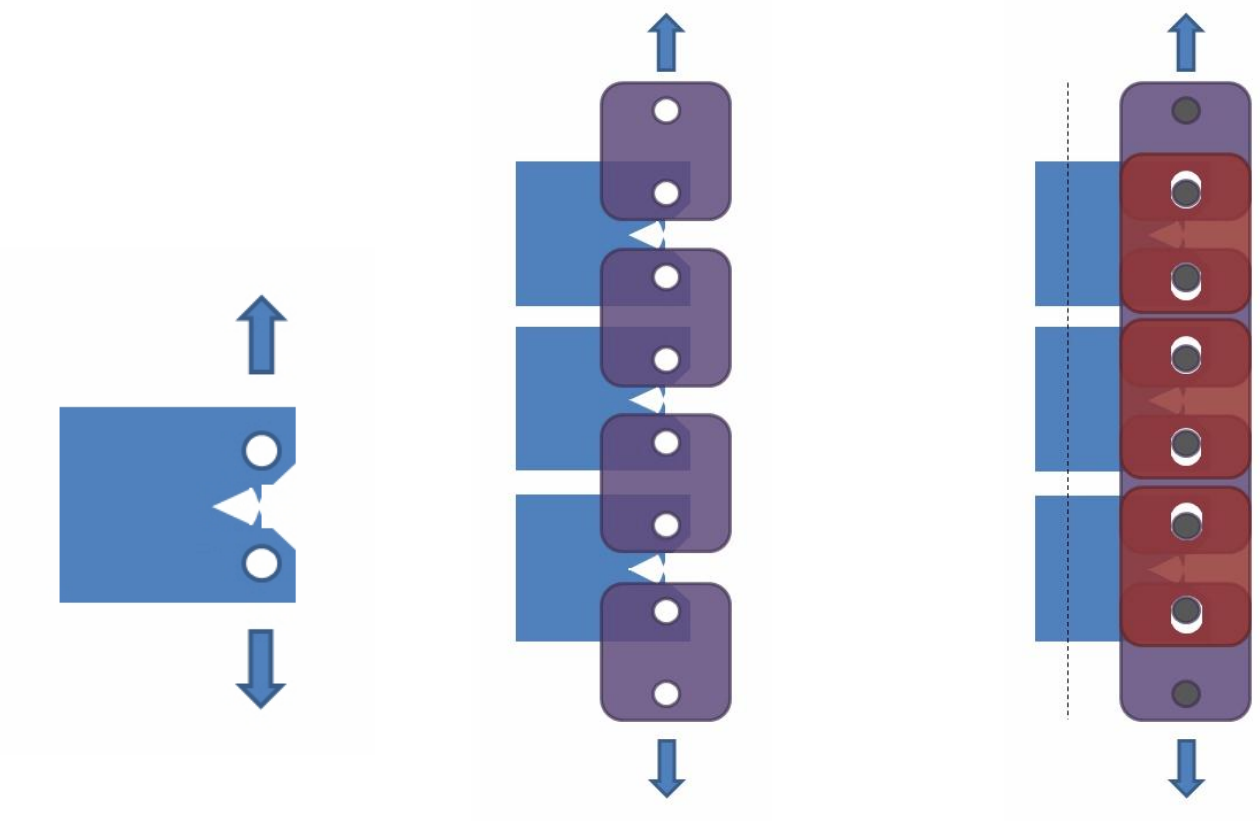


Crack growth allowed

Links carry the load after the crack has grown a preset amount
Does not allow complete failure of any specimen

# Multiple-Specimen Testing in Hydrogen

- Tall load frame to accommodate the test vessel
- 34 MPa test vessel
- 10 linked specimens must stand straight so that the last connection can be made blindly

# How it Works

- Multiple-specimen fatigue