Solids Lab: Tensile Tests

Trevor Burgoyne 7 Dec 2022 AEM 4602W, Lab Group 3Bi

Contents

Conversions

```
mm2in = 0.0393701; % in/mm
psi2mpa = 0.00689476; % MPa/psi
mpa2gpa = .001; % GPa/MPa
volts2lbs = 5620/10; % lbs/volt tensile test machine conversion
volts2in  = 2/10; % in/volt tensile test machine conversion
```

Extensometer Calibration

```
d = 0.1*mm2in; % mm -> in, micrometer distance
% d = 0.1;
V = [0.953, 0.956, 0.955]; % Volts, extensometer reading at d
V_avg = mean(V);
ext_volts2in = d/V_avg; % in/Volt, extensometer conversion
```

Metal Properties

```
l = 2.7575; % in, gage length
% Aluminim 6061
AL6061 = struct();

w = [.1955, .193, .193]; % in, sample width
t = [.118, .1115, .1155]; % in, sample thickness
AL6061.w = mean(w); % in
AL6061.t = mean(t); % in
AL6061.a = AL6061.w*AL6061.t; % in^2, cross-sectional area
AL6061.l = l; % in, gage length

wb = [.149, .1615]; % in, sample width at break
tb = [.082, .0885]; % in, sample thickness at break
AL6061.wb = mean(wb); % in
AL6061.tb = mean(tb); % in
AL6061.ab = AL6061.wb*AL6061.tb; % in^2, cross-sectional area of break
AL6061.a_red = (1 - AL6061.ab/AL6061.a)*100; % percent reduction of area at failure
AL6061.true_strain = log(AL6061.a / AL6061.ab); % unitless, true strain at failure, assumes zero volume change

AL6061.fmax = 1118.2; % lb
AL6061.xmax = 0.021; % in
AL6061.fb = 920.4; % lb
AL6061.xb = 0.024; % in




% Steel 304
SS304 = struct();

w = [.1935, .1945, .1935]; % in, sample width
t = [.1135, .118, .1135]; % in, sample thickness
SS304.w = mean(w); % in
SS304.t = mean(t); % in
SS304.a = SS304.w*SS304.t; % in^2, cross-sectional area
SS304.l = l; % in, gage length

wb = 3.37*mm2in; % in, sample width at break
tb = 1.95*mm2in; % mm->in, sample thickness at break
SS304.wb = mean(wb); % in
```

```
SS304.tb = mean(tb); % in
SS304.ab = SS304.wb*SS304.tb; % in^2, cross-sectional area of break
SS304.a_red = (1 - SS304.ab/SS304.a)*100; % percent reduction of area at failure
SS304.true_strain = log(SS304.a / SS304.ab); % unitless, true strain at failure, assumes zero volume change

SS304.fmax = 1750.7; % lb
% SS304.xmax = 0.021; % in
% SS304.fb = 1227.9; % lb
SS304.xb = 0.029; % in


% Steel 1018
SS1018 = struct();

w = [.193, .192, .1945]; % in, sample width
t = [.1135, .115, .118]; % in, sample thickness
SS1018.w = mean(w); % in
SS1018.t = mean(t); % in
SS1018.a = SS1018.w*SS1018.t; % in^2, cross-sectional area
SS1018.l = 1; % in, gage length

wb = [.1205, .123]; % in, sample width at break
tb = [.083, .083]; % in, sample thickness at break
SS1018.wb = mean(wb); % in
SS1018.tb = mean(tb); % in
SS1018.ab = SS1018.wb*SS1018.tb; % in^2, cross-sectional area of break
SS1018.a_red = (1 - SS1018.ab/SS1018.a)*100; % percent reduction of area at failure
SS1018.true_strain = log(SS1018.a / SS1018.ab); % unitless, true strain at failure, assumes zero volume change

SS1018.fmax = 1750.7; % lb
SS1018.xmax = 0.021; % in
SS1018.fb = 1227.9; % lb
SS1018.xb = 0.029; % in
```

AL6061 Test

time, Chan101 (Volts, load cell), time, Chan102 (Volts, crosshead), time, Chan103 (Volts, extensometer)

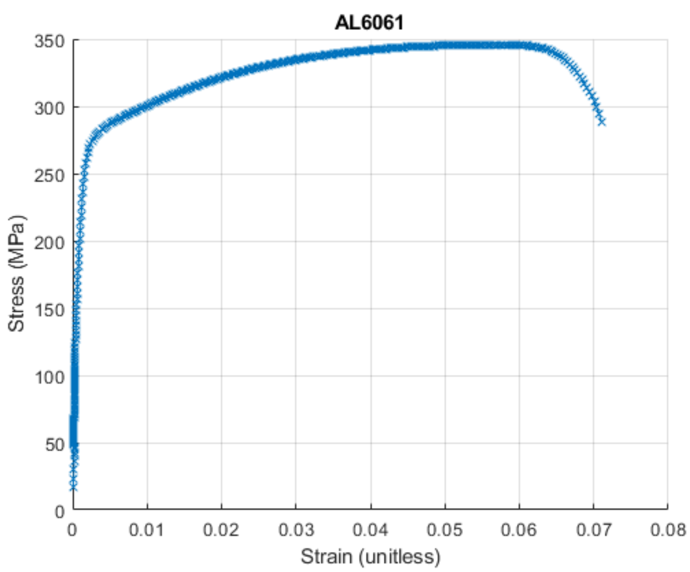
```
data = readtable('dataALTest1.csv');
idx = find(data.Chan103 == 0.345908) - 1; % idx where extensometer was removed
end_idxs = find(data.Chan101 < 0.03); % idx where sample broke
end_idx = end_idxs(1) - 1;

AL6061.volts2lbs = AL6061.fmax / max(data.Chan101); % lbs/volt using recorded max force
AL6061.volts2in  = AL6061.xb / data.Chan102(end_idx); % in/volt using recorded max displacement

AL6061.stress = (data.Chan101(2:end_idx)*AL6061.volts2lbs / AL6061.a)*psi2mpa; % MPa, engineering stress

AL6061.strain = data.Chan103(2:idx)*ext_volts2in / AL6061.w; % unitless, engineering strain
eu = AL6061.strain(end); % Last value of extensometer strain
cross_eu = data.Chan102(idx); % Volts, value of crosshead reading when extensometer was removed
AL6061.strain = [AL6061.strain', (data.Chan102(idx+1:end_idx)-cross_eu)'*AL6061.volts2in / AL6061.w + eu]'; % Use crosshead data after extensometer was removed

AL6061.tough = trapz(AL6061.strain, AL6061.stress); % MPa, toughness
AL6061.strength = AL6061.stress(idx); % MPa, ultimate strength (where necking starts)

range = 20:100; % Idx range for E calculation
AL6061.E = mean(diff(AL6061.stress(range))./diff(AL6061.strain(range))); % MPa, Young's Modulus
% P = polyfit(AL6061.strain(range),AL6061.stress(range),1);
% AL6061.E = P(1)

test = AL6061.stress ./ (AL6061.strain - .002); % Slope of .2% offset line at each point
idxs = find(test >= AL6061.E); % Find which best matches E
AL6061.yield = AL6061.stress(idxs(1)) % MPa, yield stress (.2% offset)
```

```
Warning: Column headers from the file were modified to make them valid MATLAB
identifiers before creating variable names for the table. The original column
headers are saved in the VariableDescriptions property.
Set 'VariableNamingRule' to 'preserve' to use the original column headers as
table variable names.

AL6061 =

  struct with fields:

            w: 0.1938
            t: 0.1150
            a: 0.0223
            l: 2.7575
           wb: 0.1552
           tb: 0.0852
           ab: 0.0132
```

```
         a_red: 40.6255
   true_strain: 0.5213
          fmax: 1.1182e+03
          xmax: 0.0210
            fb: 920.4000
            xb: 0.0240
     volts2lbs: 688.4451
      volts2in: 0.0082
        stress: [379×1 double]
        strain: [379×1 double]
         tough: 23.0011
      strength: 344.9134
             E: 7.6436e+04
         yield: 265.5754
```

Plot

```
figure()
hold on
% plot(AL6061.strain(1:idx), AL6061.stress(1:idx), '-x')
plot(AL6061.strain, AL6061.stress, '-x')

% range = linspace(0,0.005,100);
% plot(range, (AL6061.E/mpa2gpa)*range + .002);
xlabel('Strain (unitless)'); ylabel('Stress (MPa)'); title('AL6061');
grid on
```



SS304 Test

time, Chan101 (Volts, load cell), time, Chan102 (Volts, crosshead), time, Chan103 (Volts, extensometer)

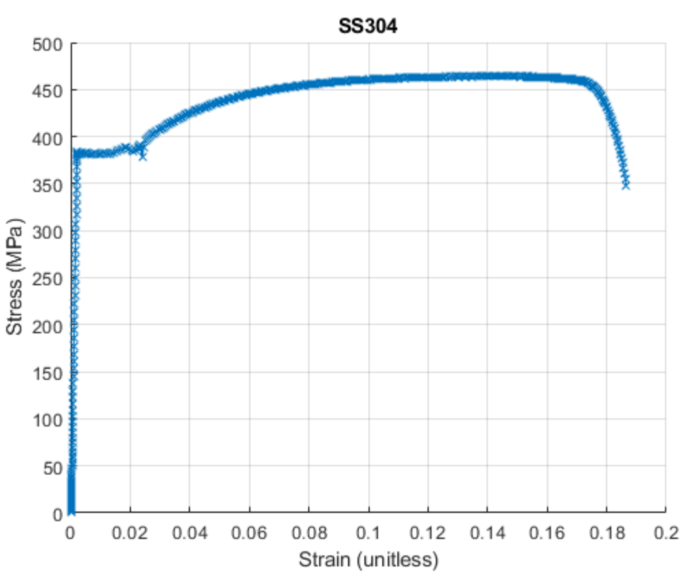
```
data = readtable('dataSS304.csv');
idx = find(data.Chan103 == 1.94125) - 1; % idx where extensometer was removed
end_idxs = find(data.Chan101 < 0.001); % idx where sample broke
end_idx = end_idxs(1) - 1;

SS304.fmax = 1500; % lb
SS304.xb = 0.029; % in

SS304.volts2lbs = SS304.fmax / max(data.Chan101); % lbs/volt using recorded max force
SS304.volts2in  = SS304.xb / data.Chan102(end_idx); % in/volt using recorded max displacement
% SS304.volts2lbs = volts2lbs;
% SS304.volts2in = volts2in;

SS304.stress = (data.Chan101(2:end_idx)*SS304.volts2lbs / SS304.a)*psi2mpa; % MPa, engineering stress

% SS304.strain = data.Chan103(2:idx)*ext_volts2in / SS304.w; % unitless, engineering strain
SS304.strain = data.Chan103(2:idx)*.05*volts2in / SS304.w; % unitless, engineering strain

eu = SS304.strain(end); % Last value of extensometer strain
cross_eu = data.Chan102(idx); % Volts, value of crosshead reading when extensometer was removed
SS304.strain = [SS304.strain', (data.Chan102(idx+1:end_idx)-cross_eu)'*SS304.volts2in / SS304.w + eu]'; % Use crosshead data after extensometer was removed

% Correct large strain offset
offset_idx = 151; % Idx where extensometer reading jumps way down
```

```
offset = SS304.strain(offset_idx-1) - SS304.strain(offset_idx);
SS304.strain(offset_idx:end) = SS304.strain(offset_idx:end) + offset;

SS304.tough = trapz(SS304.strain, SS304.stress); % MPa, toughness
SS304.strength = SS304.stress(idx); % MPa, ultimate strength (where necking starts)

range = 20:100; % Idx range for E calculation
% SS304.E = mean(diff(SS304.stress(range))./diff(SS304.strain(range))); % MPa, Young's Modulus
P = polyfit(SS304.strain(range),SS304.stress(range),1);
SS304.E = P(1);

test = SS304.stress ./ (SS304.strain - .002); % Slope of .2% offset line at each point
idxs = find(test >= SS304.E); % Find which best matches E
SS304.yield = SS304.stress(idxs(1)) % MPa, yield stress (.2% offset)
```

```
Warning: Column headers from the file were modified to make them valid MATLAB
identifiers before creating variable names for the table. The original column
headers are saved in the VariableDescriptions property.
Set 'VariableNamingRule' to 'preserve' to use the original column headers as
table variable names.

SS304 =

  struct with fields:

             w: 0.1938
             t: 0.1150
             a: 0.0223
             l: 2.7575
            wb: 0.1327
            tb: 0.0768
            ab: 0.0102
         a_red: 54.3047
   true_strain: 0.7832
          fmax: 1500
            xb: 0.0290
     volts2lbs: 595.6612
      volts2in: 0.0077
        stress: [503×1 double]
        strain: [503×1 double]
         tough: 81.7386
      strength: 463.4645
             E: 1.9831e+05
         yield: 367.4663
```

Plot

```
figure()
hold on
plot(SS304.strain(1:end), SS304.stress(1:end), '-x')
xlabel('Strain (unitless)'); ylabel('Stress (MPa)'); title('SS304');
grid on
```



SS1018 Test (No extensometer)

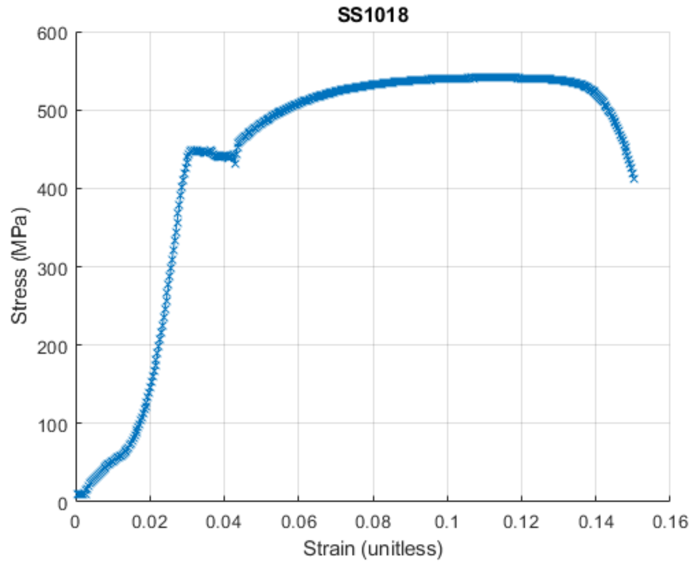
time, Chan101 (Volts, load cell), time, Chan102 (Volts, crosshead), time, Chan103 (Volts, extensometer)

```
data = readtable('dataSS1018.csv');
end_idxs = find(data.Chan101 < 0.03); % idx where sample broke
end_idx = end_idxs(1) - 1;

SS1018.volts2lbs = SS1018.fmax / max(data.Chan101); % lbs/volt using recorded max force
SS1018.volts2in  = SS1018.xb / data.Chan102(end_idx); % in/volt using recorded max displacement

SS1018.stress = (data.Chan101(2:end_idx)*SS1018.volts2lbs / SS1018.a)*psi2mpa; % MPa, engineering stress
SS1018.strain = data.Chan102(2:end_idx)*SS1018.volts2in / SS1018.l; % unitless, engineering strain

SS1018.tough = trapz(SS1018.strain*(SS1018.l/SS1018.w), SS1018.stress*(SS1018.l/SS1018.w)); % MPa, toughness
SS1018.strength = SS1018.stress(idx); % MPa, ultimate strength (where necking starts)

range = 20:100; % Idx range for E calculation
% SS1018.E = mean(diff(SS1018.stress(range))./diff(SS1018.strain(range))); % MPa, Young's Modulus
P = polyfit(SS1018.strain(range),SS1018.stress(range),1);
SS1018.E = P(1);

test = SS1018.stress ./ (SS1018.strain - .002); % Slope of .2% offset line at each point
idxs = find(test >= SS1018.E); % Find which best matches E
SS1018.yield = SS1018.stress(idxs(1)) % MPa, yield stress (.2% offset)

% Poisson ratio
```

```
Warning: Column headers from the file were modified to make them valid MATLAB
identifiers before creating variable names for the table. The original column
headers are saved in the VariableDescriptions property.
Set 'VariableNamingRule' to 'preserve' to use the original column headers as
table variable names.

SS1018 =

  struct with fields:

             w: 0.1932
             t: 0.1155
             a: 0.0223
             l: 2.7575
            wb: 0.1217
            tb: 0.0830
            ab: 0.0101
         a_red: 54.7068
    true_strain: 0.7920
          fmax: 1.7507e+03
          xmax: 0.0210
            fb: 1.2279e+03
            xb: 0.0290
      volts2lbs: 689.3470
       volts2in: 0.0082
         stress: [466×1 double]
         strain: [466×1 double]
          tough: 934.7576
       strength: 538.8684
             E: 2.3737e+05
          yield: 400.7667
```

Plot

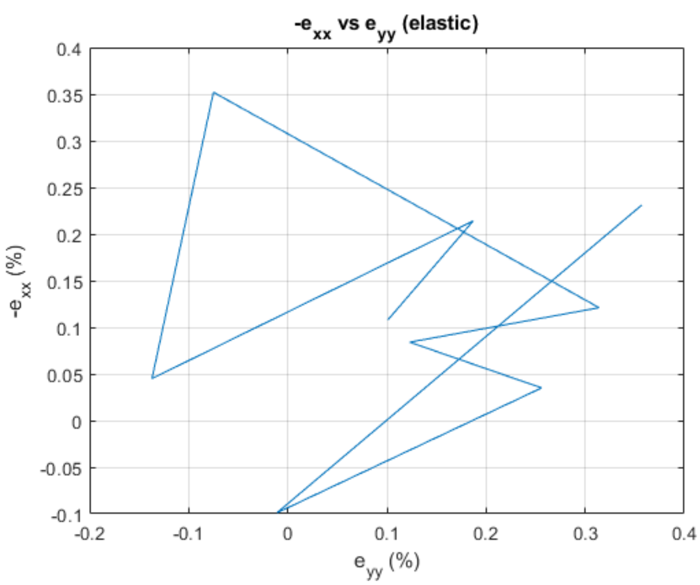
```
figure()
hold on
plot(SS1018.strain*(SS1018.l/SS1018.w), SS1018.stress, '-x')

xlabel('Strain (unitless)'); ylabel('Stress (MPa)'); title('SS1018');
grid on
```



SS1018 DIC Data (Before Yielding)

times = [30, 32, 40, 50, 60, 70, 80, 90, 100];

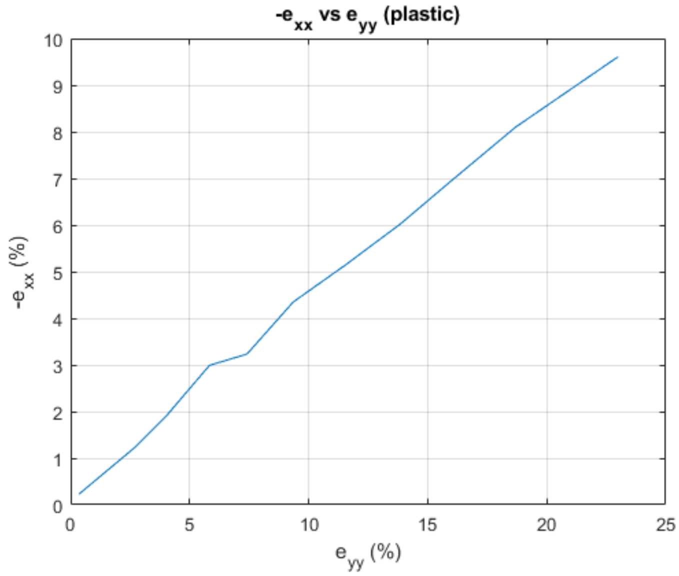
```
SS1018.exx = [-.108, -.214, -.045, -.352, -.121, -.084, -.035, 0.099, -.231];
SS1018.eyy = [.101, .187, -.137, -.075, .314, .123, .256, -.011, .357];
% SS1018.v_elastic = mean(diff(-SS1018.exx)./diff(SS1018.eyy));
P = polyfit(SS1018.eyy,-SS1018.exx,1);
SS1018.v_elastic = P(1);
figure()
plot(SS1018.eyy, -SS1018.exx); grid on;
ylabel('-e_{xx} (%)');xlabel('e_{yy} (%)');title('-e_{xx} vs e_{yy} (elastic)')
```



SS1018 DIC Data (After Yielding)

times = [100, 130, 160, 190, 220, 250, 280, 310, 340, 370, 400];

```
SS1018.exx = [-.231, -1.210, -1.939, -2.991, -3.233, -4.350, -5.174, -6.014, -6.961, -8.099, -9.607];
SS1018.eyy = [0.357, 2.650, 4.076, 5.834, 7.409, 9.352, 11.628, 13.831, 16.020, 18.689, 22.989];
% SS1018.v_plastic = mean(diff(-SS1018.exx)./diff(SS1018.eyy));
P = polyfit(SS1018.eyy,-SS1018.exx,1);
SS1018.v_plastic = P(1);
figure()
plot(SS1018.eyy, -SS1018.exx); grid on;
ylabel('-e_{xx} (%)');xlabel('e_{yy} (%)');title('-e_{xx} vs e_{yy} (plastic)')
```



Published with MATLAB® R2020b