EGR 111
Stress-Strain

The purpose of this lab is to use MATLAB to calculate the stress-strain relationship on a variety of materials.

New MATLAB commands: `format long, format short`

Resources (available on course website): `sf1045.txt, sfalum.txt`

1. Background

Engineers and materials scientists test materials such as steel and aluminum to evaluate their properties. One test is to place a bar of material in a load frame machine (see Figure 1 below) and apply a force to the material and pull it apart. As the material is pulled apart, the machine can take discrete measurements of the force that is applied and the resulting strain (change in length per unit length). From the force, one can calculate stress (force per unit area) and thus plot the stress-strain relationship for the material.

Suppose that you work for a materials testing company. You have tensile-tested a 2 inch bar of 1045 hot rolled carbon steel with a diameter of 0.505 inches using a load frame machine. Download the file, `sf1045.txt`, from the course website; it lists the *strain* (in/in) in the first column and the *force* (lbf) values in the second column measured for this bar of steel (thanks to Dr. Ken Lulay for providing the data). Below are the first few rows of the file:

```
1.00E-06  51.83
4.00E-06  69.49
8.00E-06  90.69
1.20E-05  112.35
1.50E-05  131.38
1.90E-05  146.87
2.10E-05  160.06
2.40E-05  173.77
2.70E-05  189.09
```

Figure 1: Load Frame

2. Importing Data

We can import the data into MATLAB by typing the following command:
`load sf1045.txt`

MATLAB creates a variable with the same name as the first part of the filename (`sf1045`), and since the file `sf1045.txt` contains two columns of data, the variable sf1045 will have two columns. To print the first 9 rows, type the following command: `sf1045(1:9,:)`

```
>> sf1045(1:9,:)
        ans =
            0.0000   51.8300
            0.0000   69.4900
            0.0000   90.6900
            0.0000  112.3500
            0.0000  131.3800
            0.0000  146.8700
            0.0000  160.0600
            0.0000  173.7700
            0.0000  189.0900
```

Notice all the zeros in the first column. By default, MATLAB only prints four decimal points, and since the values in the first column are so small they end up being printed as zeros. You can verify that the stored values are correct by telling MATLAB to print all of the digits with the following command: `format long`

Then when you print the first few lines you get the following:

```
>> sf1045(1:9,:)
ans =
  1.0e+002 *
   0.000000010000000   0.518300000000000
   0.000000040000000   0.694900000000000
   0.000000080000000   0.906900000000000
   0.000000120000000   1.123500000000000
   0.000000150000000   1.313800000000000
   0.000000190000000   1.468700000000000
   0.000000210000000   1.600600000000000
   0.000000240000000   1.737700000000000
   0.000000270000000   1.890900000000000
```

Notice the line "1.0e+002" which indicates that the stored values are the printed values times 1.0e+e002 (or equivalently times 100).

So the value of the first row and first column of the variable `sf1045` is

```
0.000000010000000 * 1.0e+002 = 0.0000010000000 = 1e-6
which is the value specified in the file (see above).
```

Verify that this value is correct by having MATLAB print out just the value of the first row and first column using indexing:

```
>> sf1045(1,1)
ans =
    1.000000000000000e-006
```

You can switch back to the default print format using the following command: `format short`

For convenience, we can separate the two columns of the variable into two individual vectors. The first column is strain and the second column is force.

```
>> strain = sf1045(:,1);  % strain (in/in)
>> force = sf1045(:,2);   % force (lbf)
```

3. Calculating Stress-Strain

Stress is defined as force exerted per unit area, and the units of stress are pounds per square inch (psi). The formula for calculating stress is given below where r is the radius, and d is the diameter of the rod (in inches).

$$Stress = \frac{force}{area} = \frac{force}{\pi r^2} = \frac{force}{\pi \left(\frac{d}{2}\right)^2}$$

Exercise 1: Write a script file to plot the stress-strain curve for 1045 Hot Rolled Steel

a. Import the file sf1045.txt using the load command (`load sf1045.txt`). This command will load the data into a two-column variable called `sf1045`.

b. Define your inputs:
   a. A variable representing the strain of the steel bar (in/in).
   b. A variable representing the force applied to the steel bar (lbf).
   c. A variable representing the steel bar's diameter (in).

c. Compute the stress using the formula given above.

d. Plot stress versus strain with strain on the x-axis and stress on the y-axis. Be sure to label the axes and title the plot as shown in Figure 2 below.

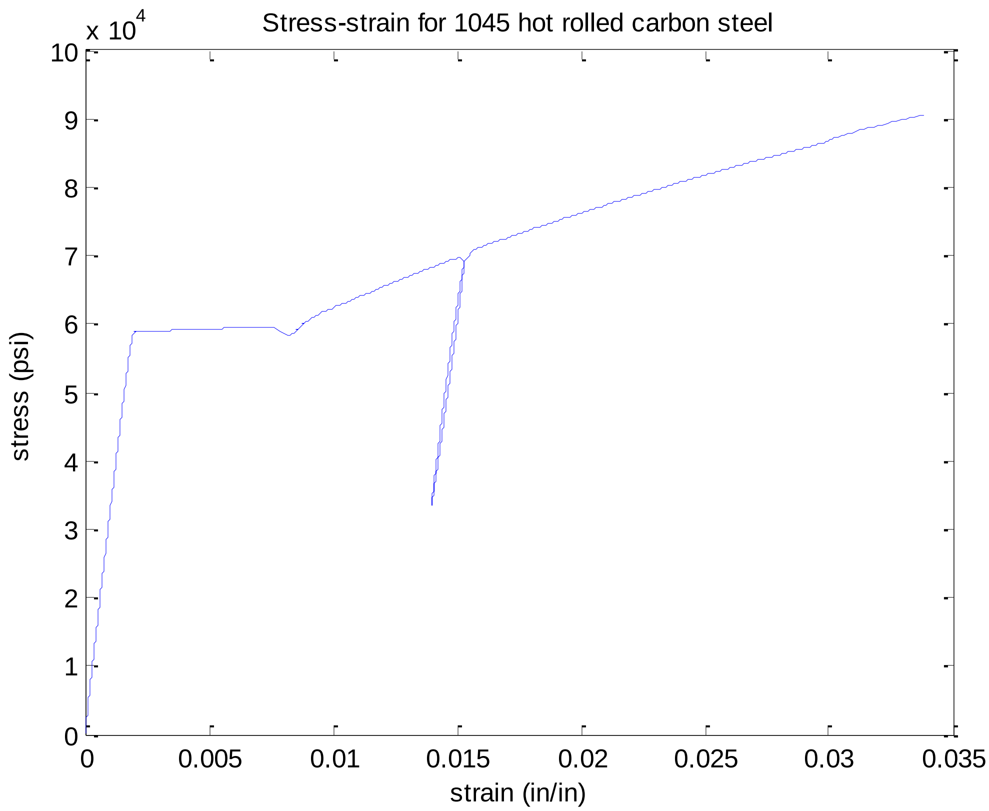

Figure 2. Plot of Strain v. Stress for 1045 Hot Rolled Steel

Checkpoint 1: Show the instructor your script file and plot from Exercise 1.

Exercise 2

Download the file `sfalum.txt` from the course website. This data is for a 2 inch long bar of aluminum alloy (specifically 2024-T351) with a diameter of 0.505 inches. Modify your script so that it calculates the strain and plots stress-strain for both materials on the same graph. Make sure you label the axes, title the plot, and add a legend as shown below in Figure 3.

To learn more about the available colors and line styles, type `help plot`.

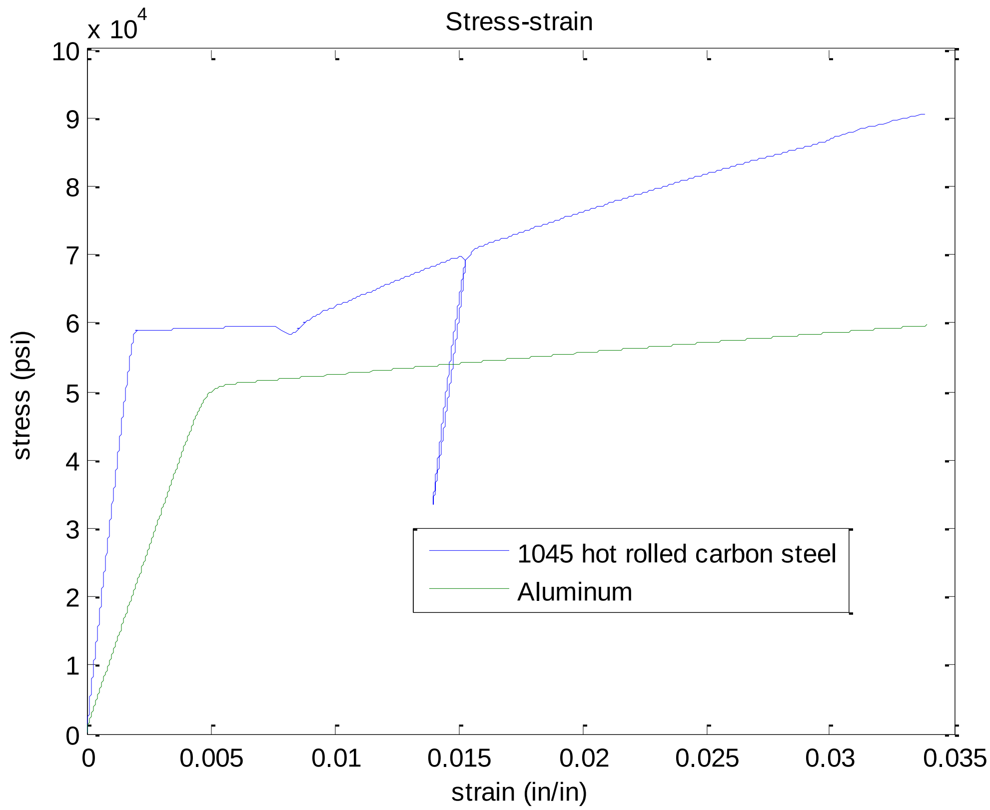

Figure 3. Plot of Strain v. Stress for Steel and Aluminum

Checkpoint 2: Show the instructor your script file and plot from Exercise 2.