Intro Learning Module - Plot sigma_x vs. inner radius (Take 2)

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Plot $_x$ vs. r_i (Take 2)

Vectorize $_x$ Calculation

Again, we pick MATLAB's brain on vectorization:

Home (tab) > Documentation (icon) > Search: *Vectorization* > Vectorization (with book icon)

Go through the example. We'll vectorize our program by replacing loops with array operations. Since the syntax for array operations very closely resembles that for corresponding scalar operations, let's create our program starting from *beam.m* rather than loopy *beam2.m*.

Select *beam.m* in the Editor by clicking on its name at the bottom.

Editor (tab) > Save > Save As

Enter `beam3.m` for filename. Confirm that you are editing *beam3.m*.

MATLAB's vectorization example shows you how you can create the vector *ri* using the **:** operator. Let's check how we can use this animal. At the command prompt, type

```
0.5:0.1:1.5
```

You can see that this creates a row vector with the first and last elements being 0.5 and 1.5, respectively. Each successive element is incremented by 0.1. The general format is *start:increment:end*.

In your program, convert *ri* to a vector using the syntax above:

```
12 - ri = 1e-2*(0.5:0.1:1.5);
```

We now come to a key idea about vectorization. In the succeeding statement for calculating *I*, we have the term *ri^4*. To understand how MATLAB interprets it, consider the following simple example of how MATLAB interpets the ^ operator for matrices:

$$\alpha = [\alpha_1 \ \alpha_2]$$
$$\alpha\text{^}2 = [\alpha_1 \ \alpha_2][\alpha_1 \ \alpha_2]$$

So it tries to do a matrix multiplication with . It'll of course hiss and stamp its feet in complaint when it tries to multiply a 1x2 matrix with itself. But we are not looking for a matrix multiplication. We'd like each element to be raised to the given power.

$$\alpha.\text{^}2 = [\alpha_1^2 \ \alpha_2^2]$$

Note that this is achieved by preceding the ^ operator with the period character (.). The period character can be used with other arithmetic operators such as * and /. Chew over this as it is a subtle but powerful feature. For more info, see

Home (tab) > Documentation (icon) > Search: *arithmetic operators* > Arithmetic Operators + - * / \ ^ '

So in the *I* statement, we replace `ri^4` with `ri.^4`

```
13 - I = pi*(ro^4 - ri.^4)/4;
```

What should we do in the succeeding *sigma_x* statement to vectorize it? When you try to divide by *I*, MATLAB will try a matrix operation. So we strategically employ our period character:

```
14 - sigma_x = 1e-6*M*ro./I
```

This tells MATLAB that each element of *sigma_x* needs to be divided by the corresponding element of *I*, namely:

sigma_x(1) = 1e-6*M*ro/I(1)
sigma_x(2) = 1e-6*M*ro/I(2)
blah blah blah

Save your program. In the command window, clear the Workspace and run the program:

```
>> clear all;
>> beam3
```

How do your values of *sigma_x* correspond to the values from *beam2.m*? Mine are the same ... yipppee!

Plot $_x$ vs. r_i: Take 2

Recycle the plot section from our program in Step 3. Copy this section and append it to your current program:

```
%Plot sigma_x vs. ri
plot(1e2*ri,sigma_x,'-r');
xlabel('r_i (cm)');
ylabel('\sigma_x at O (MPa)');
```

Save and run to create the plot. Let's make this plot spiffy enough that it can be included in a formal report that you submit to your boss. This can be done by expanding this section as shown below:

```
%Plot sigma_x vs. ri
figure(1); %Create figure #1
clf; %Clear current figure
h=plot(1e2*ri,sigma_x,'-r');
set(gca,'Box','on','LineWidth',2,...
'FontName','Helvetica',...
'FontSize',14);
%Set axis properties
set(h,'LineWidth',2);
%Set linewidth for curve
xlabel('r_i (cm)');
ylabel('\sigma_x at O (MPa)');
title('Bending stress');
axis square; %Make axis box square
```

We'll soon see what each of these statements does. For now, **replace** the plot section in your program with the above code snippet using copy-and-paste.

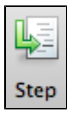
Save and run to create the plot. What differences do you notice in the plot?

To see the effect of each statement in this code segment, let's step through it using the debugger. Close you figure window. Let's pause the execution at the `figure(1)` statement by setting a "breakpoint" at this statement: click in the column between the statement and the line number. A red dot will appear in this column as below.

```
20 • figure(1);
```

Run the program. A green arrow appears in this statement indicating that the program has paused just before this statement.

```
20 •➡figure(1);
```

Execute this statement by clicking on the *step* icon 

in the Editor. This should bring up the *Figure 1* window. Note that the green arrow moves to the next statement indicating that execution is paused there.
Click again on the *step* icon. ***clf*** will clear anything in the current figure i.e. figure 1. This means you start with a clean slate.

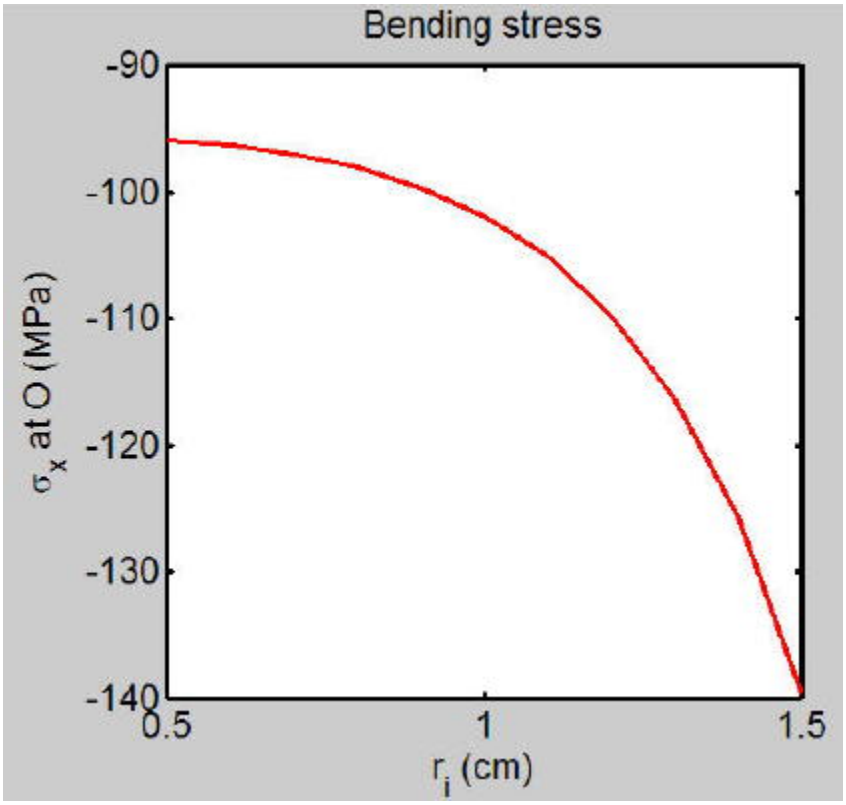
Step through the plot command. This will create the basic plot. The plot command returns a "handle"; we have assigned that to the variable h. Look at this variable in the Workspace. We need this plot handle to manipulate the properties of the plot, just as you'd need the key to my office to manipulate its contents.

```
22 -➡h=plot(1e2*ri,sigma_x,'-r');
```

Keep an eye on the axes lines and labels in your figure as you step through the ***set(gca,...)*** command. Did you see that this command changed the font and line styles for the axes? gca stands for *get current axes* handle; once we have the handle, we can manipulate the axes properties (yup, same as my office). You can use this statement after any plot command; if you have multiple plot commands for the same figure, this statement needs to be used only once.

Now we will make the curve in the plot thicker. Keep an eye on the $_x$ curve as you step through the ***set(h,...)*** statement. Did you notice a change in the line style?

Retain an eye on your figure as you step through the remaining statements. You should end up, as below, with a nice-looking plot with legible lines and text. The ***axis square*** statement makes the current axis box square in size.



Exit debug mode by clicking on the 

icon in the Editor.

See my entire program here (right click and select save target as).

I strongly suggest that you be environmentally friendly and recycle the above plot commands to produce good quality figures. Since I am a nice guy, I have summarized this below as a "plot template" for your convenience; you can copy-and-paste and modify this code snippet in your future programming endeavors.

```
figure(1); %Create figure #1
clf; %Clear current figure
h=plot(,,'');
set(gca,'Box','on','LineWidth',2,...
'FontName','Helvetica',...
'FontSize',14);
%Set axis properties
set(h,'LineWidth',2);
%Set linewidth for curve
xlabel('');
ylabel('');
title('');
axis square; %Make axis box square
```

Go to Step 5: Plot x vs. ri (Take 3: File Input/Output)

Go to all MATLAB Learning Modules