Workshop 2 Rheology

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> Santosh Dasari

Objective

1. Develop MATLAB code to import experimental data, then plot the data and fit a model that most accurately reflects the trend shown by the data to classify the fluid as having: Newtonian, shear thinning, shear thickening, and/or Bingham plastic behavior.
2. Construct a viscosity curve from the shear stress and shear rate data.

Matlab Code

```
% Clear workspace and command window
clear; clc;

% Define the filenames for the datasets
filenames = {'data1.txt', 'data2.txt', 'data3.txt', 'data4.txt'};

% Initialize figure for viscosity curves
figure;

% Loop through each dataset
for i = 1:length(filenames)
    % Import data using readtable
    data = readtable(filenames{i});
    shear_rate = data.Var1;
    shear_stress = data.Var2;

    % Calculate shear stress at 1.5 s^-1
    stress_at_1_5 = interp1(shear_rate, shear_stress, 1.5);
    fprintf('Shear stress at 1.5 s^-1 for %s: %.4f Pa\n', filenames{i},
stress_at_1_5);

    % Create viscosity curve
    viscosity = shear_stress ./ shear_rate;

    % Create subplot for each dataset
    subplot(2, 2, i);
```

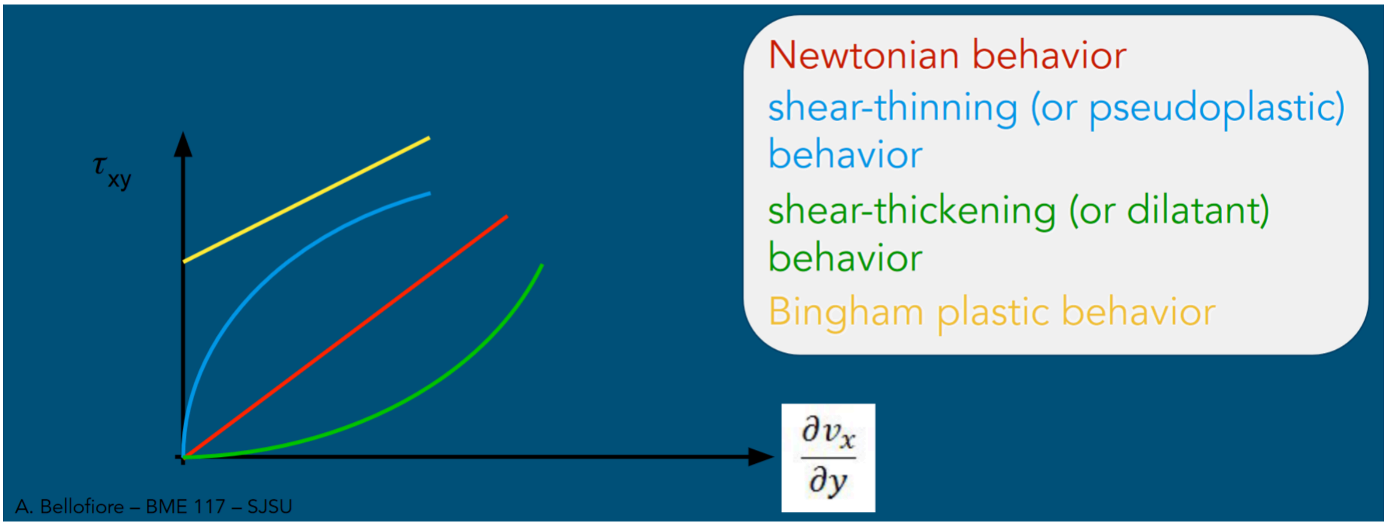
```
    semilogx(shear_rate, viscosity, 'o-');
    xlabel('Shear Rate (s^{-1})');
    ylabel('Viscosity (Pa·s)');
    title(sprintf('Viscosity Curve for %s', filenames{i}));

    % Open Curve Fitting Tool for each dataset
    cftool(shear_rate, shear_stress);
end
```

What the code does:

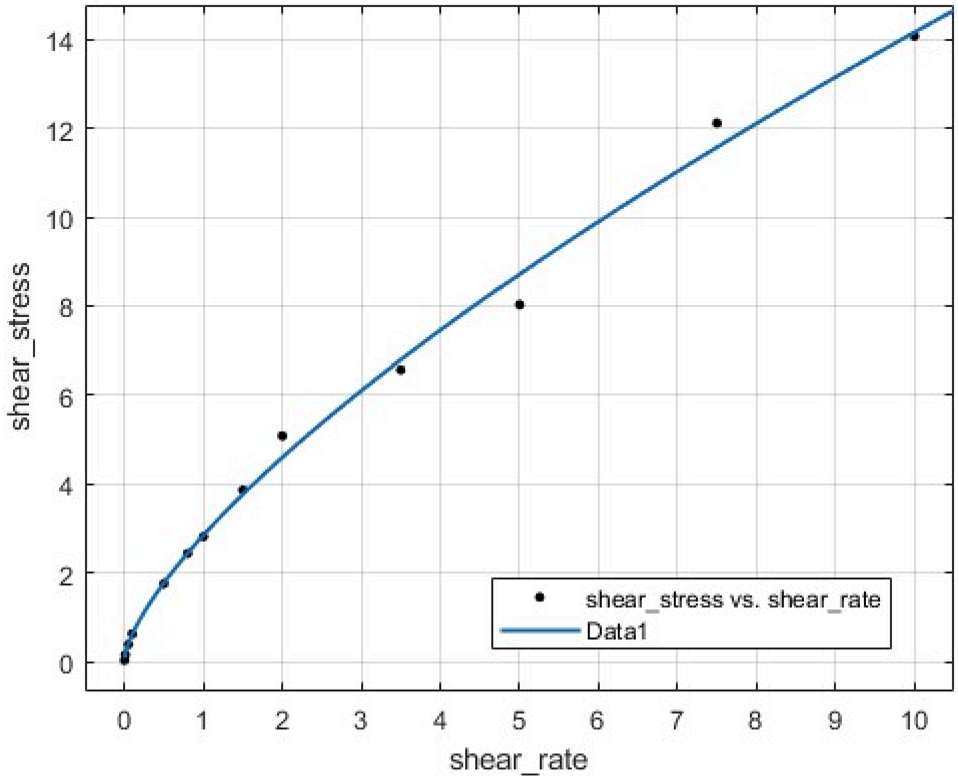
- Defines filenames for the datasets.
- Initializes a figure for plotting viscosity curves.
- Loops through each dataset:
  - Imports data from each file using `readtable`.
  - Extracts shear rate and shear stress columns.
  - Interpolates shear stress at 1.5 s^-1 and prints the result.
  - Calculates viscosity by dividing shear stress by shear rate.
  - Creates a viscosity curve plot in a subplot.
  - Opens each dataset's MATLAB Curve Fitting Tool (`cftool`).
    - Once the `cftool` is open, I manually selected the best possible fit type to go with the plot made by MATLAB. I also adjusted the order of polynomial and power term value order to get the best possible visual fit.

Results:

Data result compared to the image below from lecture.



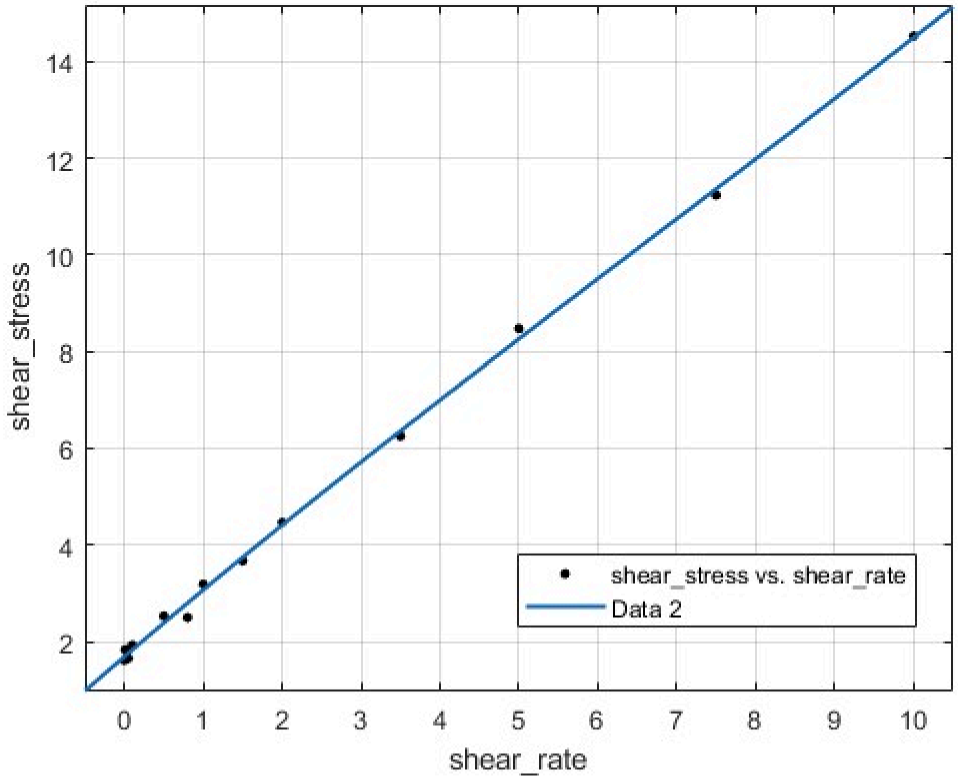
Dataset 1




```
Power Curve Fit (power2)
f(x) = a*x^b+c

Goodness of Fit
               Value
SSE           1.0699
R-square      0.9958
DFE           10.0000
Adj R-sq      0.9949
RMSE          0.3271
```

Based on the power function fit of the data1, we can see that it follows a shear-thinning behavior with the R^2 value of 0.9988.

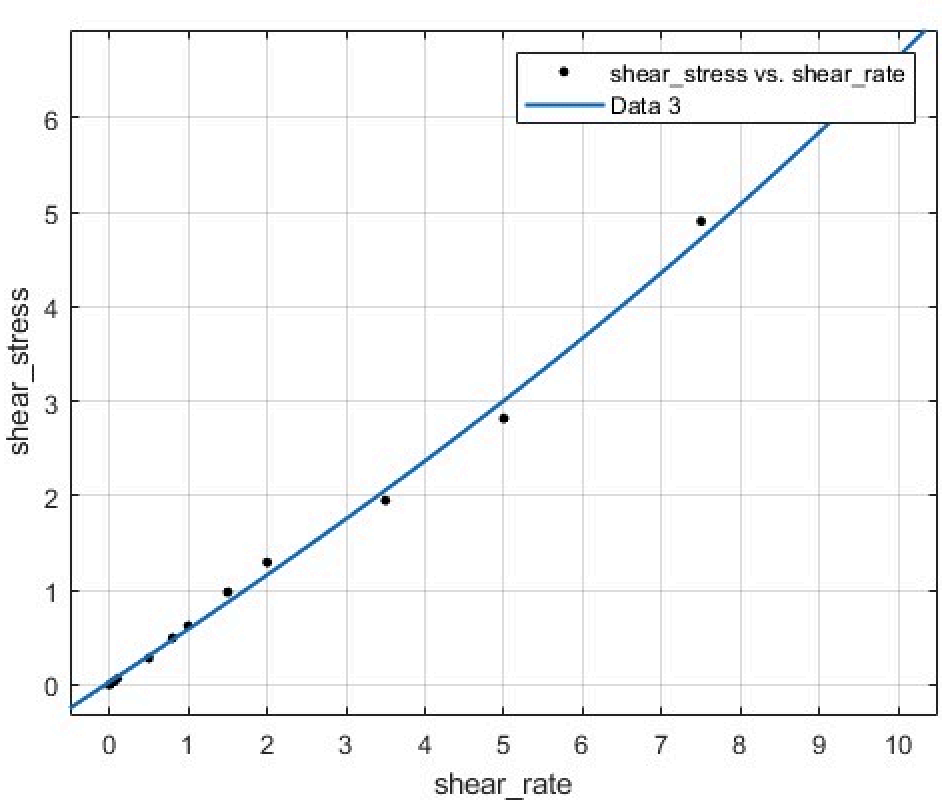
Dataset 2




```
Polynomial Curve Fit (poly3)
f(x) = p1*x^3 + p2*x^2 + p3*x + p4

Goodness of Fit
             Value
SSE          0.2489
R-square     0.9988
DFE          9.0000
Adj R-sq     0.9984
RMSE         0.1663
```

Based on the polynomial fit of the data1, we can see that it follows a Bingham Plastic behavior with the R^2 value of 0.9988. This is plastic and not Newtonian because the shear stress is at about 2Pa when the strain rate is zero.

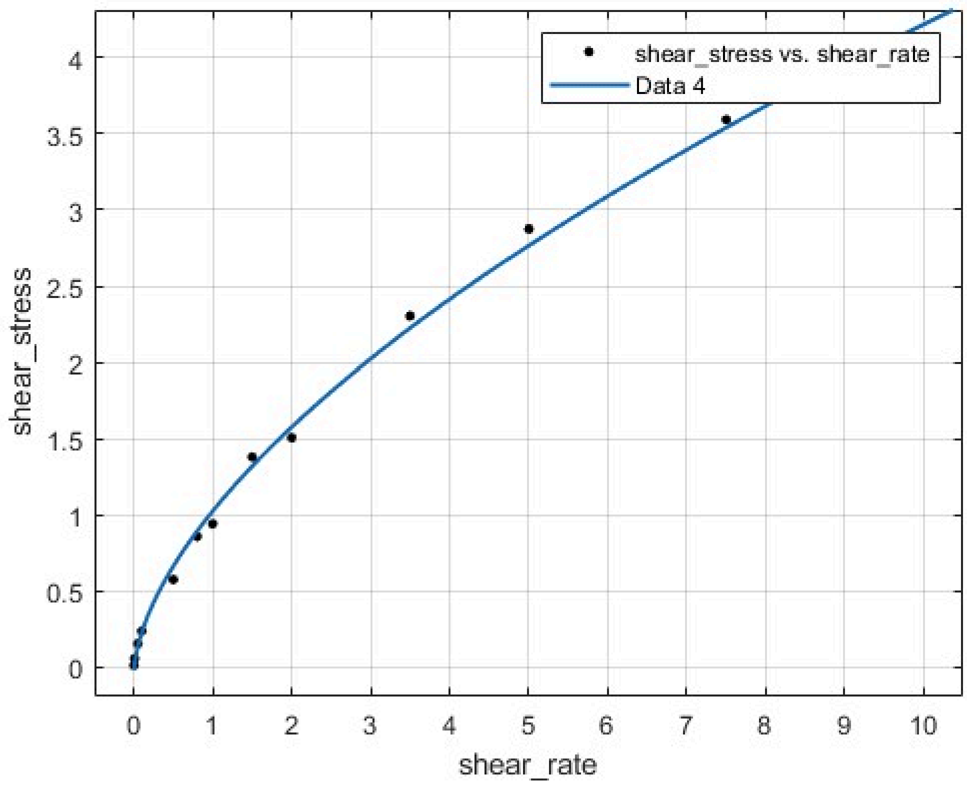
Dataset 3




```
Polynomial Curve Fit (poly3)
f(x) = p1*x^3 + p2*x^2 + p3*x + p4
Goodness of Fit
            Value
SSE         0.1161
R-square    0.9978
DFE         9.0000
Adj R-sq    0.9970
RMSE        0.1136
```

Based on the polynomial function fit of the data1, we can see that it follows an inconclusive behavior as the graph is mostly linear(Newtonian) and has shear-thickening behavior at the end. We need more data points—the R^2 value of 0.9978.

Dataset 4




```
Power Curve Fit (power2)
f(x) = a*x^b+c
Goodness of Fit
             Value
SSE          0.0598
R-square     0.9974
DFE          10.0000
Adj R-sq     0.9969
RMSE         0.0773
```

Based on the polynomial fit of the data1, we can see that it follows a Shear-Thinning behavior with the R^2 value of 0.9974.

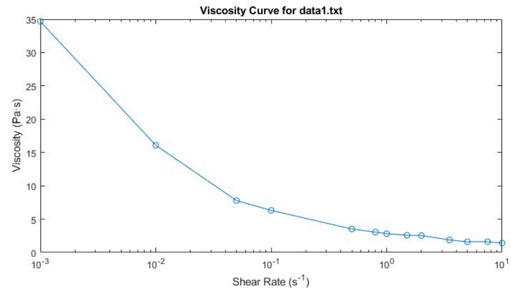
Highest Shear Stress Value

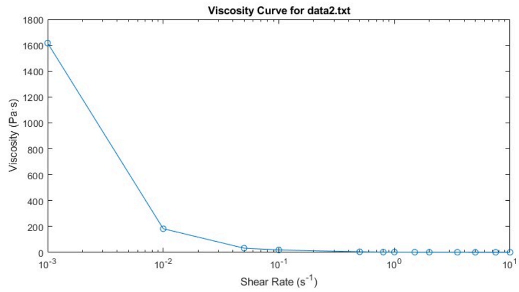
MATLAB Output

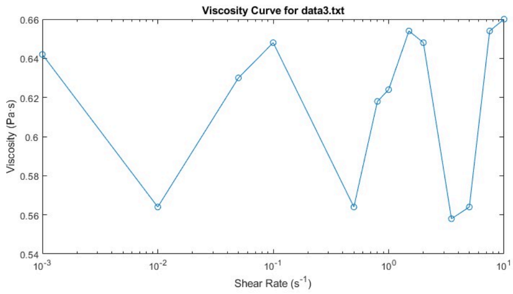
```
Shear stress at 1.5 s^-1 for data1.txt: 3.8656 Pa
Shear stress at 1.5 s^-1 for data2.txt: 3.6750 Pa
Shear stress at 1.5 s^-1 for data3.txt: 0.9810 Pa
Shear stress at 1.5 s^-1 for data4.txt: 1.3796 Pa
>>
```

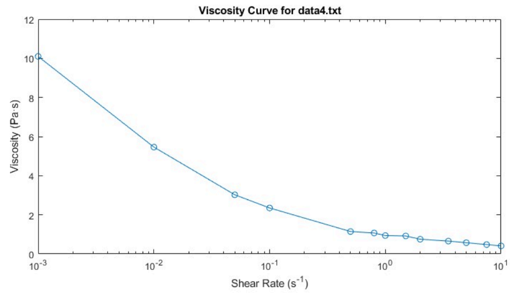
Fluid from data 1 has the Highest Shear stress at 1.5 s^-1.

Viscosity VS Shear Rate









Dataset 1: Shear-thinning behavior. The viscosity curve supports this behavior, as shear-thinning fluids display a decrease in viscosity with increasing shear rate, which aligns with the power law model fit.

Dataset 2: Bingham plastic behavior. The viscosity curve for this dataset should reflect a constant viscosity at low shear rates (indicating yield stress) before decreasing, supporting the model.

Dataset 3: This dataset shows inconclusive results, with a mostly linear viscosity curve that aligns with the Newtonian behavior at lower shear rates and slight shear-thickening at higher rates.

Dataset 4: Shear-thinning behavior is again reflected in the viscosity curve as viscosity decreases with increasing shear rate.