Orange Level Problem

Program to calculate coefficient of discharge for orifice meter and nozzle meter ,   plot graphical variations for Cd vs Re for various Beta values

Introduction

Orifice meters and nozzle meters are differential pressure flow meters used to measure the flow rate of fluids through a pipe. They work by introducing a constriction, which causes a pressure drop proportional to flow velocity.

Orifice Meter

An orifice meter uses a thin, sharp-edged plate with a circular hole to create the constriction. It is simple, cost-effective, and widely used, but causes significant energy loss due to sharp flow separation and turbulence.

Nozzle Meter

A nozzle meter uses a smooth, contoured nozzle to accelerate flow, resulting in lower energy loss compared to an orifice meter. It provides more accurate measurements at high flow rates and is suitable for permanent installations.

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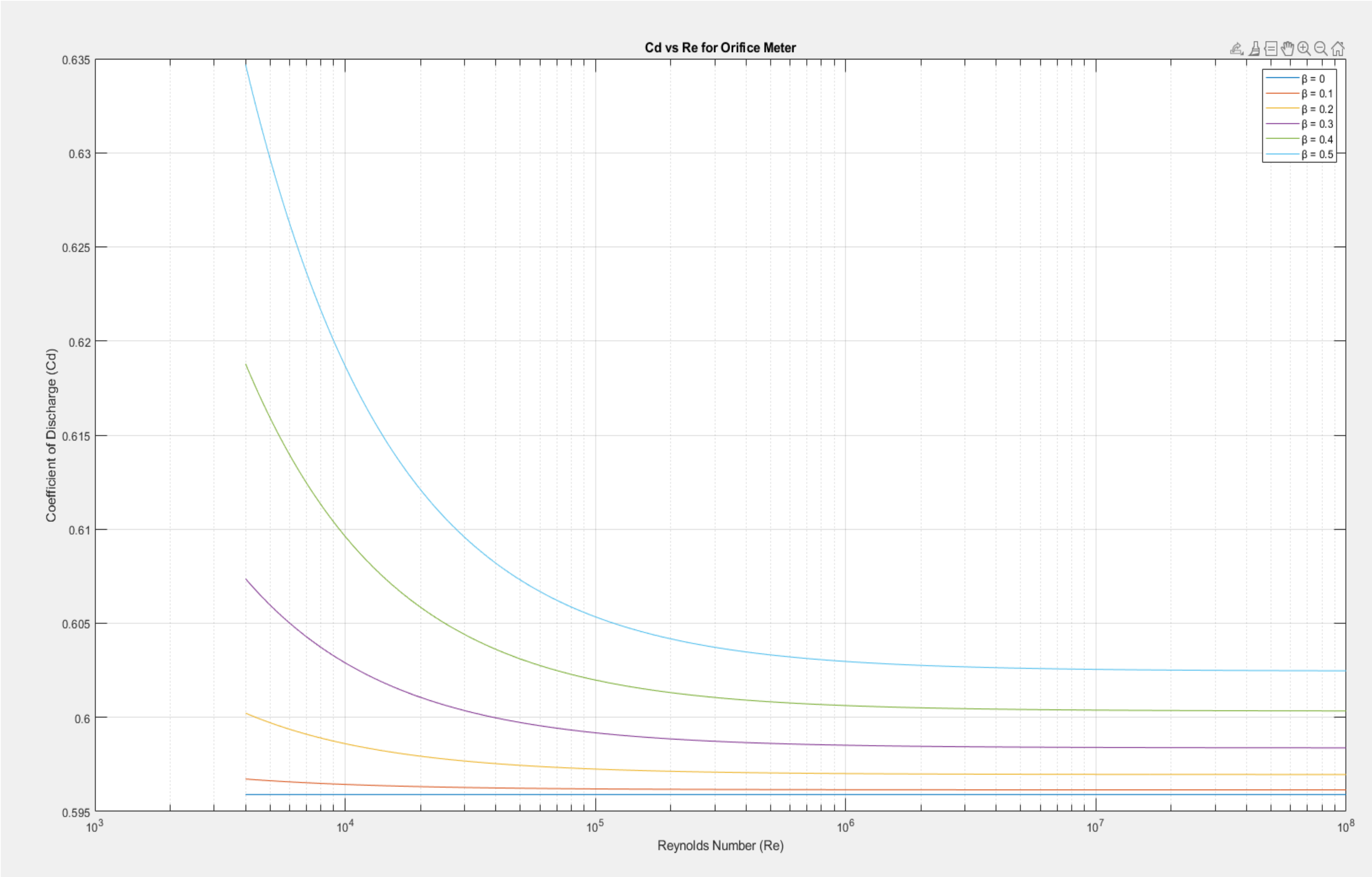
Subject: Mechanics of Fluids and Fluid Machinery

Matlab Code

```
clc;
clear;
close all;

% Constants
rho = 1000;        % Density of water (kg/m^3)
mu = 0.001;        % Dynamic viscosity (Pa.s)

% Reynolds number range
Re = logspace(log10(4e3), 8, 500); % From 1e3 to 1e6

% Beta ratios to evaluate
beta_vals = [0,0.1,0.2,0.3, 0.4, 0.5];

% Preallocate
Cd_orifice = zeros(length(beta_vals), length(Re));
Cd_nozzle = zeros(length(beta_vals), length(Re));

% Calculate Cd for each beta and Re
for i = 1:length(beta_vals)
    beta = beta_vals(i);

    % Orifice meter empirical formula (simplified ISO 
5167 approx.)
    Cd_orifice(i, :) = 0.5959 + 0.0312 * beta^2.1 - 
0.184 * beta^8 + ...
                       (91.71 * beta^2.5) ./ 
(Re.^0.75);
```

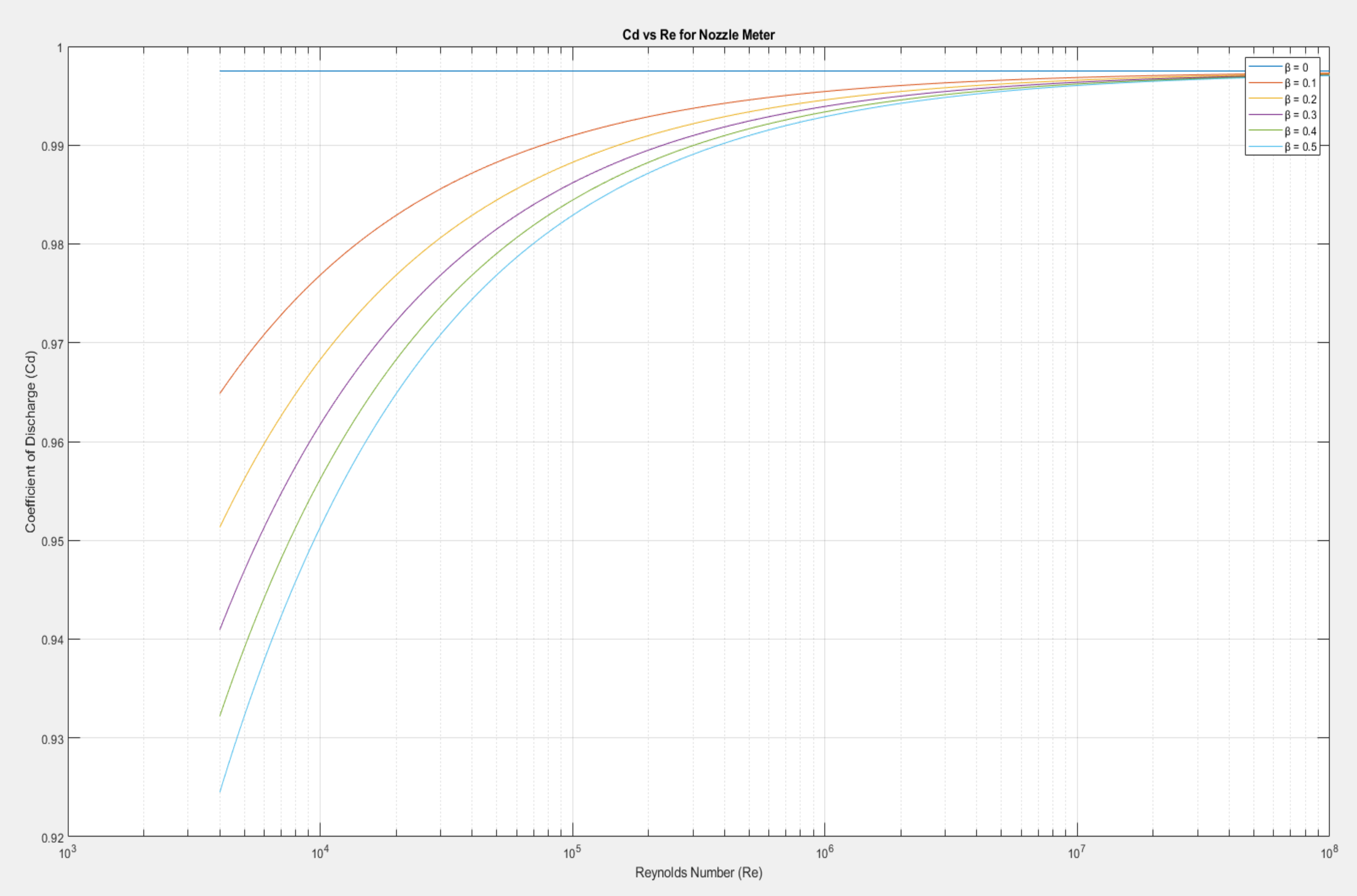
```
    % Nozzle meter empirical formula
    Cd_nozzle(i, :) = 0.9975 - (6.53 * beta^0.5) ./
(Re.^0.5);
end

% Plotting
figure;
for i = 1:length(beta_vals)
    semilogx(Re, Cd_orifice(i, :), 'DisplayName', ['β
= ' num2str(beta_vals(i))]);
    hold on;
end
xlabel('Reynolds Number (Re)');
ylabel('Coefficient of Discharge (Cd)');
title('Cd vs Re for Orifice Meter');
legend show;
grid on;

figure;
for i = 1:length(beta_vals)
    semilogx(Re, Cd_nozzle(i, :), 'DisplayName', ['β
= ' num2str(beta_vals(i))]);
    hold on;
end
xlabel('Reynolds Number (Re)');
ylabel('Coefficient of Discharge (Cd)');
title('Cd vs Re for Nozzle Meter');
legend show;
grid on;
```



Cd vs Re for Orifice Meter
Coefficient of Discharge (Cd)
Reynolds Number (Re)
0.635
0.63
0.625
0.62
0.615
0.61
0.605
0.6
0.595
10^3
10^4
10^5
10^6
10^7
10^8
β = 0
β = 0.1
β = 0.2
β = 0.3
β = 0.4
β = 0.5

Orifice Meter – Inferences

- Cd decreases and stabilizes around 0.595 at high Reynolds numbers.
- Different beta ratios produce distinct Cd values that **do not converge** at high Re.
- This indicates that **geometrical losses dominate** even when viscous losses are minimal.
- At low Re, both viscous and geometric losses reduce Cd significantly.
- The meter is simple but introduces more permanent pressure losses.



Cd vs Re for Nozzle Meter
Coefficient of Discharge (Cd)
Reynolds Number (Re)
1
0.99
0.98
0.97
0.96
0.95
0.94
0.93
0.92
10^3
10^4
10^5
10^6
10^7
10^8
β = 0
β = 0.1
β = 0.2
β = 0.3
β = 0.4
β = 0.5

Nozzle Meter – Inferences

- Cd values are generally higher and **converge** to a common value (~0.99) as Re increases.
    - This suggests **better flow recovery** and minimal geometric disruption.
    - At low Re, there's a small deviation due to viscous effects.
    - As Re increases, viscous losses become negligible, and **Cd stabilizes quickly**.
- Nozzle meters are more efficient for high-Re applications due to smoother geometry.

Reference

Dr. V Krishna's Notes

Chatgpt (https://chatgpt.com/share/680652bc-e924-800d-9597-671a29314157)(Detailed chats of discussions regarding the project with chatgpt)

The Internet