

1 Numerical calculation using Matlab

Terminal velocity of solid particles in the fluid can be determined from;

$$u_t = \sqrt{\frac{4g(\rho_p - \rho)D_p}{3C_D\rho}}$$

u_t = terminal velocity, D_p = particle size, ρ_p = particle density

ρ = fluid density, μ = fluid viscosity, C_D = drag coefficient, Re = Reynolds number

$C_D = 24 / Re$: $Re < 0.1$

$C_D = (24 / Re)(1 + 0.14Re^{0.7})$: $0.1 \leq Re \leq 1000$

$C_D = 0.44$: $1000 \leq Re \leq 350\,000$

$C_D = 0.19 - 8 \cdot 10^4 / Re$: $Re \geq 350\,000$

$Re = D_p u_t \rho / \mu$

$G = 9.806 \text{ m/s}^2$

Assumption: only one particle and no wall effect for this problem

Case1:

Solid: shape: sphere size $D_p = 0.2 \text{ mm}$. $\rho_p = 1800 \text{ kg/m}^3$

Liquid: $\rho = 995 \text{ kg/m}^3$, $\mu = 8.931 \times 10^{-4} \text{ kg/(m*s)}$

Case2:

Solid: particle shape: sphere size $D_p = 0.5 \text{ mm}$. $\rho_p = 1800 \text{ kg/m}^3$

Liquid: $\rho = 995 \text{ kg/m}^3$, $\mu = 8.931 \times 10^{-4} \text{ kg/(m*s)}$

Case3:

Solid: particle shape: sphere size $D_p = 1.0 \text{ mm}$. $\rho_p = 1800 \text{ kg/m}^3$

Liquid: $\rho = 995 \text{ kg/m}^3$, $\mu = 8.931 \times 10^{-4} \text{ kg/(m*s)}$

Case4:

Solid: particle shape: sphere size $D_p = 1.5 \text{ mm}$. $\rho_p = 1800 \text{ kg/m}^3$

Liquid: $\rho = 995 \text{ kg/m}^3$, $\mu = 8.931 \times 10^{-4} \text{ kg/(m*s)}$

Case5:

Solid: particle shape: sphere size $D_p = 2.0 \text{ mm}$. $\rho_p = 1800 \text{ kg/m}^3$

Liquid: $\rho = 995 \text{ kg/m}^3$, $\mu = 8.931 \times 10^{-4} \text{ kg/(m*s)}$

1.1 **Write** an algorithm (sequence) for terminal velocity calculation. [10]

1.2 **Check** the following code written for this problem. If there is any error in the program, circle the errors and write the correct code. Add, remove or rewrite some parts of the code with the correct one. [40]

1.3 **Find** the terminal velocity of the solid particle for each case. [10]

% terminal velocity of solid particles in the fluid

% u_t = terminal velocity, dp = particle size, rop = particle density

% ro = fluid density, vis = fluid viscosity, cd = drag coefficient

`syms $u_t, g, rop, ro, dp, cd, vis$`

% `a=[]` to install diameters of particle

% `b=[]` to install terminal velocity of particle, re = reynolds number

`a=[]; b=[]; g= 9.806 m/s^2;`

```
ro=995; vis=8.931*10(-4);  
  
for i=1:4  
  
case '1'  
  
    dp=0.2e-03; rop=1800;  
  
case '2'  
  
    dp=0.5e-03;  
  
case '3'  
  
    dp=1.0e-03;  
  
case '4'  
  
    dp =1.5e-03;  
  
else  
  
    dp=2.0e-03;  
  
end  
  
e1:=1; n=1;  
  
ut=0.5; initial guess of ut  
  
while (e1>=0.0001 and n<=50)  
  
    ut=sqrt(4*g*(rop-ro)*dp/(3*cd*p))  
  
re = dp*ut*ro/vis  
  
if re < 0.1  
  
    cd=24/re  
  
else if and(re>=0.1, re<=1000)  
  
    cd=(24/re)*(1+0.14re0.7)  
  
else if and(re>1000,re<=350000)  
  
    cd=0.44  
  
else if re=> 350000  
  
    cd=0.19-8*10(-4)/re
```

```
end

e1=|ut-uti|

uti=ut

end

a=[a dp]

b=[b ut]

end

figure (1)

plot (a b)

xlabel("particle diameter")

ylabel(" terminal velocity")

end
```

2 Find the solution of the following linear programming problem

A utility requires the blend of coals that its burns contain no more than 0.6% sulfur, 0.05% phosphorus and 2 % ash. Four different types of makeup coal are available, with their characteristics and costs shown below. Because of a restricted supply of coal #2, it can constitute no more than one-half of the blend. How should the makeup coals be mixed in order to meet the above constraints and also get a minimum cost for the utility ?

Coal #	% Sulphur	% Phosphorus	%Ash	Cost, \$/ton
1	0.2	0.05	2	30
2	1.0	0.06	3	15
3	0.5	0.03	1	25
4	0.7	0.03	2	20

2.1) Based on one ton of final mixed coal, **what** is the value of $x_1 + x_2 + x_3 + x_4$?
Where x_1, x_2, x_3 and x_4 are the amounts of coal types 1, 2, 3 and 4, respectively. [2]

2.2) This is maximization or minimization problem (objective), **mark** on the number. [2]

1) Maximization

2) Minimization

2.3) **What are the variables we have to vary to get the answer?** _____ . [2]

2.4) **Is the LP formula below correct?**

$$\text{Cost} = 30x_1 + 15x_2 + 25x_3 + 20x_4$$

$$\text{Minimize cost} = \text{minimize } z = 30x_1 + 15x_2 + 25x_3 + 20x_4$$

Subject to

$$x_1 + x_2 + x_3 + x_4 = 1$$

$$0.2x_1 + 1x_2 + 0.5x_3 + 0.7x_4 \leq 0.6$$

$$0.05x_1 + 0.06x_2 + 0.03x_3 + 0.03x_4 \leq 0.05$$

$$2x_1 + 3x_2 + x_3 + 2x_4 \leq 2$$

$$x_2 < 0.5$$

$$x_1, x_2, x_3, x_4 \geq 0$$

If it is incorrect, **correct it to give the rig solution** and solve this problem by using “**Solver**” in Excel. [24]

2.5) Use “**linprog**” in Matlab to find this LP problem (get the solution of the problem). If you think the formula above is wrong, assume that you can use the formula in this problem).

[30]

Note

$x = \text{linprog}(f, A, b)$ solves the linear programming problem:

$$\min_x f^*x \quad \text{subject to: } A^*x \leq b$$

$x = \text{linprog}(f, A, b, Aeq, beq)$ solves the problem above while additionally satisfying the equality constraints $Aeq^*x = beq$.

$x = \text{linprog}(f, A, b, Aeq, beq, LB, UB)$ defines a set of lower and upper bounds on the design variables, x , so that the solution is in the range $LB \leq X \leq UB$. Use empty matrices for LB and UB

if no bounds exist. Set $LB(i) = -\text{Inf}$ if $X(i)$ is unbounded below; set $UB(i) = \text{Inf}$ if $X(i)$ is unbounded above.

What are the matrices used in the command “linprog**” to solve LP problem**

$f = ?$

$A = ?$

$Aeq = ?$

$B = ?$

$Beq = ?$

3 Tables 1 shows the concentration of Acetic acid Versus time for $C_{A0}=2 \text{ mol/dm}^3$ and $C_{B0} = 2 \text{ mol/dm}^3$.

Time (min)	Concentration C_a , mole/dm ³
0	2.0
120	1.705
150	1.647
180	1.595
210	1.546
240	1.501
270	1.46
300	1.421

3.1) Write this table in Matlab code as a matrix **A** for time and concentration above. **What is the size of matrix “A”?** [8]

3.2) If we already have matrix **A**, the following program shows the code in Matlab for how to get a vector for time and concentration C_a , separately. Is the entire program correct? If it is incorrect, change to the correct code. [10]

```
%data analysis
% concentration of acetic acid versus time for  $C_{A0} = 2 \text{ mole/dm}^3$  and  $C_{B0} = 2 \text{ mole/dm}^3$ 
%matrix below shows time in the first column and concentration in the second column
a=( 0 2;120 1.705;150 1.647;180 1.595;210 1.546;240 1.501; 270 1.46;300 1.421)
time=a[:,1]; conc=a[:,2];
plot(time, conc)
```

3.3) what is the coefficients if we estimate this curve with 1st, 2nd and 3rd order polynomials? And which order estimation is the most suitable for this problem? Why? [12]

1st-order

2nd-order

3rd-order