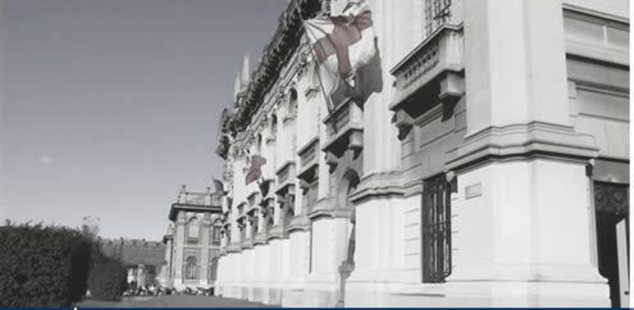
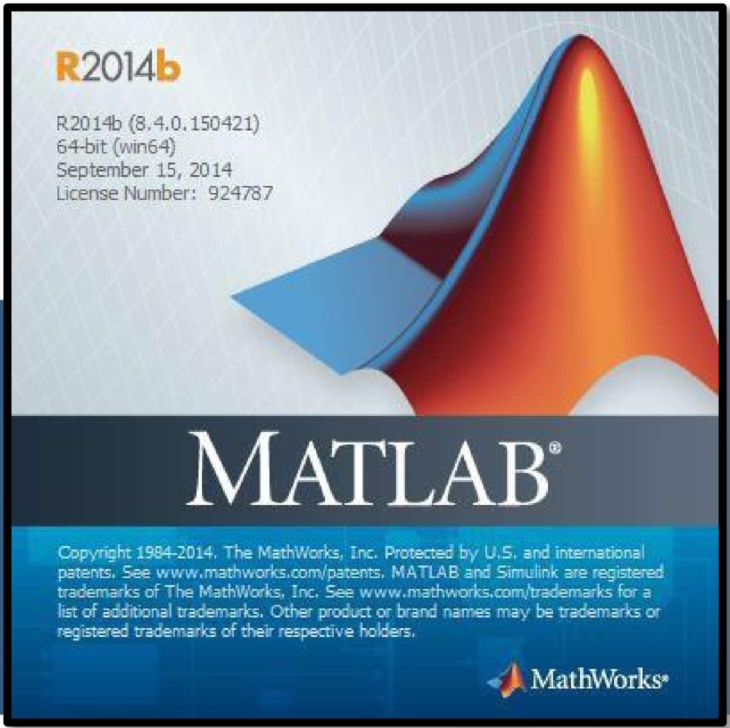




POLITECNICO DI MILANO

Esercitazione 5 - Soluzioni

Corso di Strumentazione e Controllo di impianti chimici

Prof. Davide Manca

PSE-Lab

Ese 5.1 – Serbatoio di stoccaggio riscaldato

1. Modellare l'andamento della temperatura del liquido nel serbatoio, considerandolo chiuso agli scambi materiali.

$H = 1.5\ m$

$\rho = 1000\ \frac{kg}{m^3}$

$D = 0.5\ m$

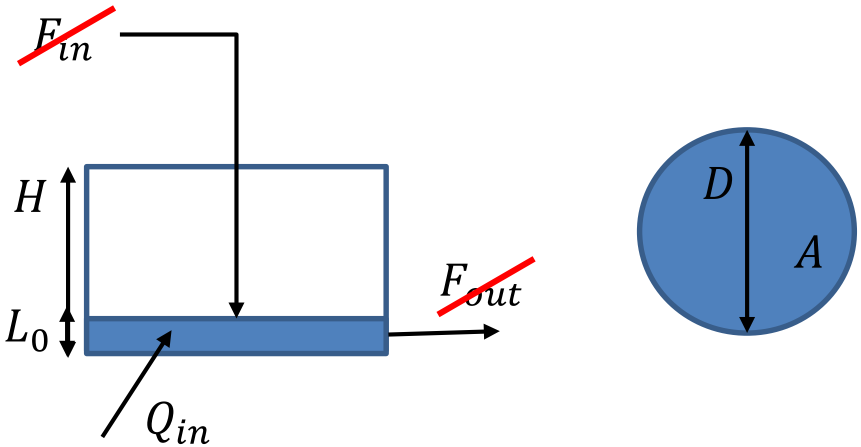
$c_p = 4186\ \frac{J}{kg\ K}$

$F_{in} = F_{out} = 0\ m^3/min$

$L_0 = 1\ m$

$Q_{in} = 5\ kW$

$T_{in} = 25\ °C$



Bilancio Materiale:

$$\frac{dm}{dt} = \dot{m}_{in} - \dot{m}_{out} = 0 \longrightarrow \frac{\rho A dh}{dt} = 0 \longrightarrow$$ Il livello rimane costante

Bilancio Entalpico:

$$\frac{dH}{dt} = Q_{in} \longrightarrow \frac{dT}{dt} = \frac{Q_{in}}{ro*h*c_{p*A}}$$

HOW TO

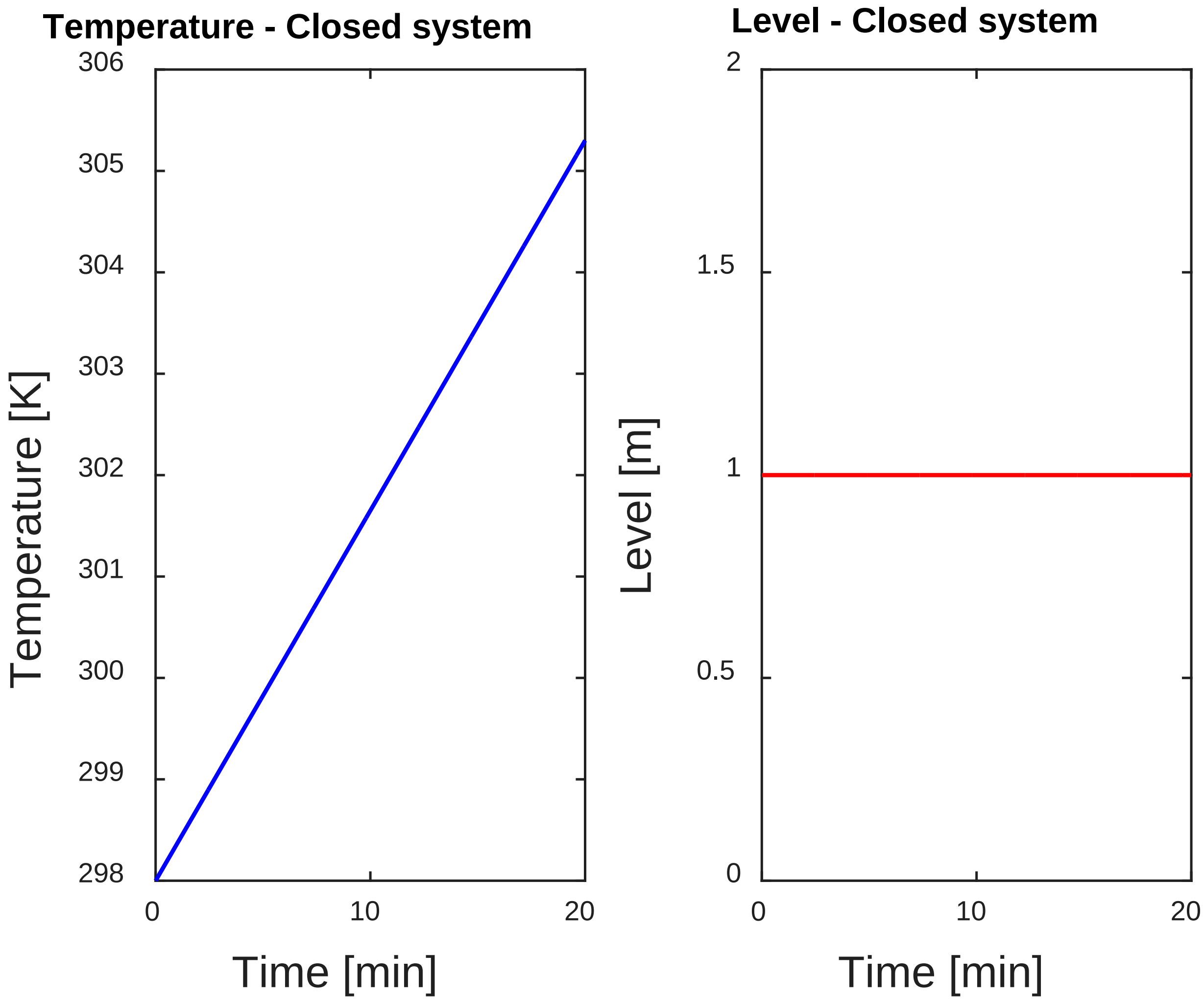
```
function DinamicaSerbatoioEnt1 %E5.1 Sistema chiuso agli scambi materiali

clc
clear all
close all

global  A Qin ro cp Fin Fout
% Dati
Fin = 0; %m3/min
Fout = Fin;
D = 0.5; %m
H_vessel = 1.5; %m
A = pi*D^2/4; %m2
Tin = 25 + 273; % [K]
Qin = 5000*60; %[J/min]
L0 = 1; % [m]
ro = 10^3; % [kg/m3]
cp = 4186; % [J/kg K]
tspan = [0:0.05:20]

% Comando
[t,Yout] = ode113(@eqTemperatura,tspan,[L0 Tin]);
```

```
figure(1)
hold on
subplot(1,2,1)
plot(t,Yout(:,2),'b','LineWidth',1.3)
set(gca,'fontsize',11)
title('Temperature - Closed system','FontSize',14)
xlabel('Time [min]','FontSize',18)
ylabel('Temperature [K]','FontSize',18)

subplot(1,2,2)
plot(t,Yout(:,1),'r','LineWidth',1.3)
set(gca,'fontsize',11)
title('Level - Closed system','FontSize',14)
xlabel('Time [min]','FontSize',18)
ylabel('Level [m]','FontSize',18)

end % chiudo la function DinamicaSerbatoioEnt1
```

Sistema ODE

```
function dy = eqTemperatura(t,Y)

global  A Qin ro cp Fin Fout

l = Y(1); % level
T = Y(2); % temperature

dy(1,:) = (Fin - Fout)/A;
dy(2,:) = 1/(A*l)*(Qin/(ro*cp));
end
```

Results


Temperature - Closed system
Temperature [K]
306
305
304
303
302
301
300
299
298
0
10
20
Time [min]
Level - Closed system
Level [m]
2
1.5
1
0.5
0
0
10
20
Time [min]

Ese 5.2 – Serbatoio di stoccaggio (sitema adiabatico)

A partire dalla condizione iniziale stazionaria con le portate materiali in ingresso ed in uscita equivalenti (durata 10 minuti), si prevedano i seguenti scenari, in successione:

1) Riduzione della portata uscente Fout a 0 m3/min per 10 min
2) Riduzione della portata entrante Fin a 5 m3/min per 18 min

$D = 8\,m \qquad H = 6\,m$

$F_{in} = 10\,m^3/min$

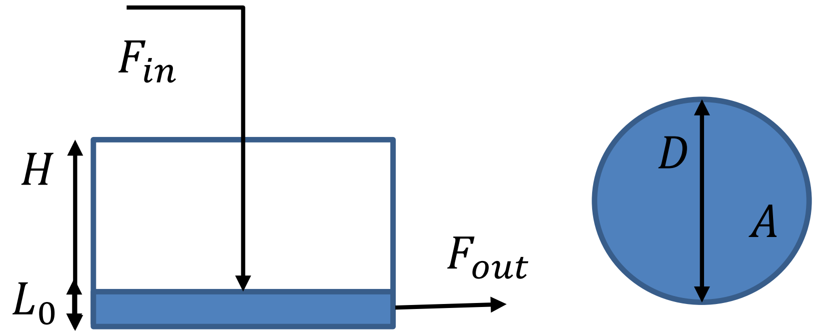
$L_0 = 2.5\,m$

$U = 0.1\,\frac{kW}{m^2 K}$

$c_p = 4186\,\frac{J}{kg\,K}$

$T_{in} = 60\,°C$

$\rho = 1000\,\frac{kg}{m^3}$



Bilancio Materiale:

$$\frac{dm}{dt} = \dot{m}_{in} - \dot{m}_{out} \longrightarrow \frac{\rho A dh}{dt} = \rho\,(F_{in} - F_{out}) \longrightarrow \frac{dh}{dt} = \frac{1}{A}(F_{in} - F_{out})$$

Bilancio Entalpico:

$$\frac{dH}{dt} = H_{in} - H_{out} \longrightarrow \rho A h c_p \frac{dT}{dt} = \rho c_p F_{in} * \left(T_{in} - T_{ref}\right) - \rho c_p F_{out} * \left(T - T_{ref}\right) - \rho c_p * \left(T - T_{ref}\right) * (F_{in} - F_{out})$$

Ese 5.2 – Serbatoio di stoccaggio (sitema non adiabatico : dispersione di calore)

A partire dalla condizione iniziale stazionaria con le portate materiali in ingresso ed in uscita equivalenti (durata 10 minuti), si prevedano i seguenti scenari, in successione:

1) Riduzione della portata uscente Fout a 0 m3/min per 10 min
2) Riduzione della portata entrante Fin a 5 m3/min per 18 min

$D = 8\,m \qquad H = 6\,m$

$F_{in} = 10\,m^3/min$

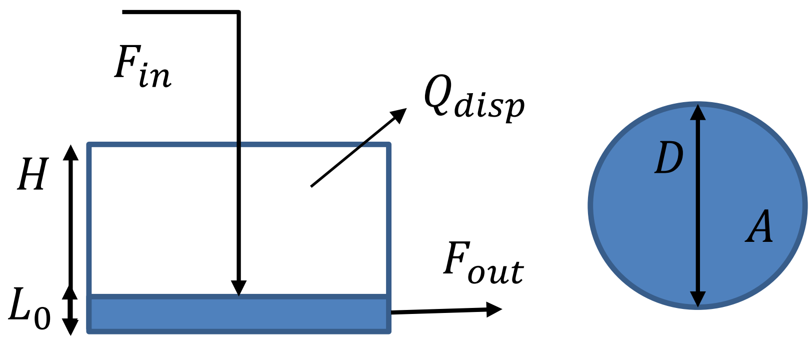
$L_0 = 2.5\,m$

$U = 0.1\,\frac{kW}{m^2K}$

$c_p = 4186\,\frac{J}{kg\,K}$

$T_{in} = 60\,°C$

$\rho = 1000\,\frac{kg}{m^3}$



Bilancio Materiale:

$$\frac{dm}{dt} = \dot{m}_{in} - \dot{m}_{out} \longrightarrow \frac{\rho A dh}{dt} = \rho\,(F_{in} - F_{out}) \longrightarrow \frac{dh}{dt} = \frac{1}{A}(F_{in} - F_{out})$$

Bilancio Entalpico:

$$\frac{dH}{dt} = H_{in} - H_{out} - Q_{disp} \longrightarrow \rho A h c_p \frac{dT}{dt} = \rho c_p F_{in} * (T_{in} - T_{ref}) - \rho c_p F_{out} * (T - T_{ref}) - \rho c_p * (T - T_{ref}) * (F_{in} - F_{out}) - Q_{disp}$$

$$Q_{disp} = U * A_{exc} * (T - T_{amb})$$

HOW TO

```
function DinamicaSerbatoioEnt2 % E5 Caso 2
Adiabatic vs NonAdiabatic system
clc
clear all
close all
global  A Tin ro cp Tref Tamb U D
% Dati
Fin = 10; %[m3/min] in condizione di stazionarietà (i primi 10 min)
Fout = Fin;
D = 8; %[m]
H_vessel = 6; % [m]
A = pi*D^2/4; %[m2]
Tin = 60 + 273; % [K]
Tref = 25 + 273;  % [K]
Tamb = Tref;
U = 100*60; % J/minm2K coeff di scambio con l'esterno
L0 = 2.5; % [m]
ro = 10^3; % [kg/m3]
cp = 4186; % [J/kg K]
tspan = [0:0.05:50]; %min

% Caso ADIABATICO : non DISPERDO CALORE nell’ambiente
[t,Yout] = ode113(@eqTemperatura,tspan,[L0 Tin]);
```

Grafici

```
figure(1)
hold on
subplot(2,2,1)
plot(t,Yout(:,2),'b','LineWidth',1.3)
set(gca,'fontsize',11)
title('Temperature - Adiabatic
system','FontSize',12)
xlabel('Time [min]','FontSize',18)
ylabel('Temperature [K]','FontSize',18)
xlim([0 50])

subplot(2,2,2)
plot(t,Yout(:,1),'r','LineWidth',1.3)
set(gca,'fontsize',11)
title('Level - Adiabatic system','FontSize',12)
xlabel('Time [min]','FontSize',18)
ylabel('Level [m]','FontSize',18)
xlim([0 50])
```

Grafici

```
% Caso non ADIABATICO : DISPERDO CALORE
 [t,Yout1] = ode23s(@eqTemperatura2,tspan,[L0 Tin]);

hold on
subplot(2,2,4)
plot(t,Yout1(:,1),'r','LineWidth',1.3)
set(gca,'fontsize',11)
title('Level - NonAdiabatic system','FontSize',12)
xlabel('Time [min]','FontSize',18)
ylabel('Level [m]','FontSize',18)

subplot(2,2,3)
plot(t,Yout1(:,2),'b','LineWidth',1.3)
set(gca,'fontsize',11)
title('Temperature - NonAdiabatic system','FontSize',12)
xlabel('Time [min]','FontSize',18)
ylabel('Temperature [K]','FontSize',18)
xlim([0 50])

end % Chiudo la function principale
```

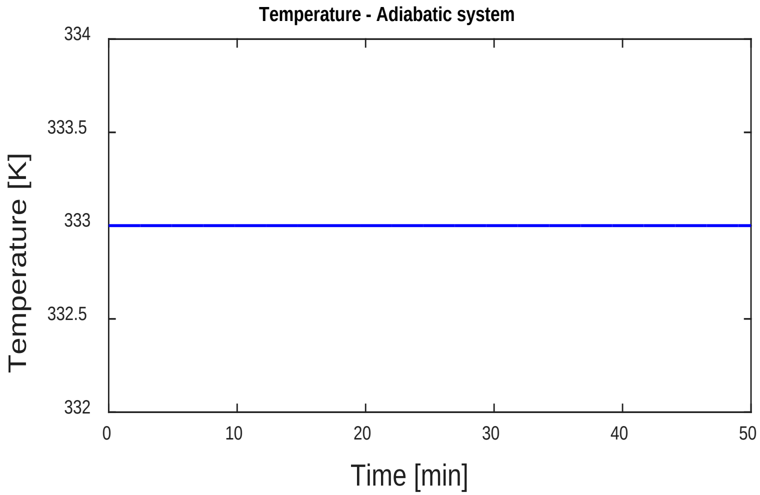
Sistema ODE

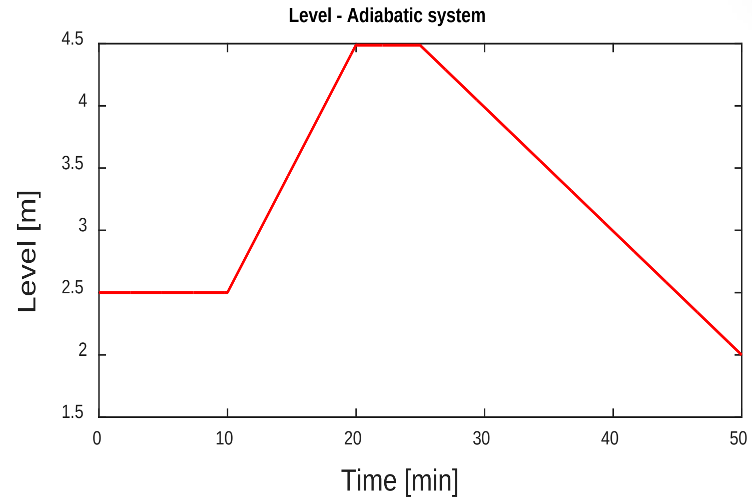
```
function dy = eqTemperatura(t,Y) % Sistema ODE caso ADIABATICO
global  A Tin

Y(1) = Level
Y(2) = Temperature
 if t <= 10
    Fin = 10;
    Fout = 10;
elseif t > 10 && t <= 20
    Fin = 10;
    Fout = 0;
elseif t> 20 && t <= 25
    Fout = 10;
    Fin = 10;
else
    Fout = 10;
    Fin = 5;
end

dy(1,:) = (Fin - Fout)/A;
dy(2,:) = 1/(A*Y(1))*( Fin * (Tin - Y(2)) + Fout * (Y(2) - Y(2)));
end
```

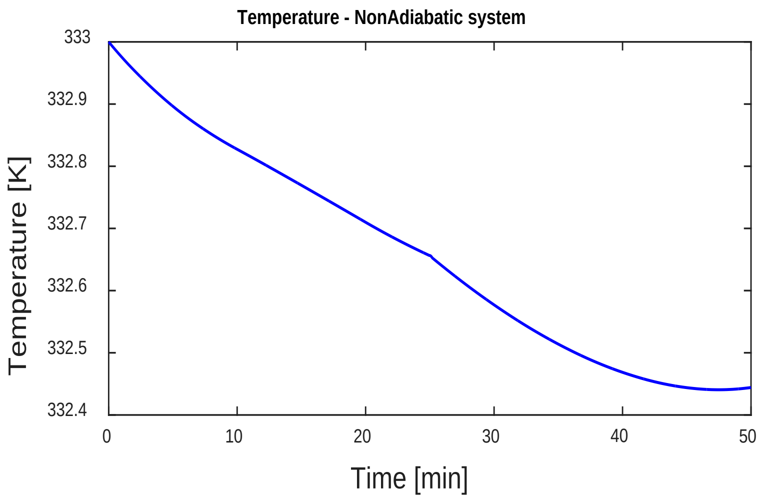
Sistema ODE

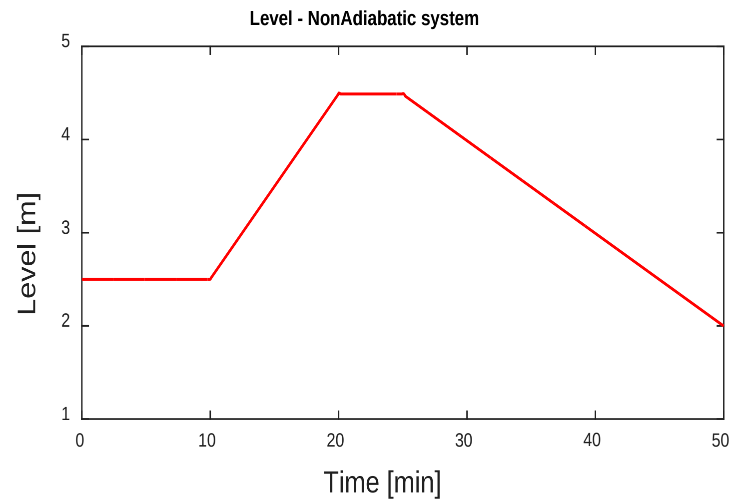
```
function dy = eqTemperatura2(t,Y) % Sistema ODE caso non ADIABATICO
global  A Tin ro cp Tref Tamb U D

if t <= 10
    Fin = 10;
    Fout = 10;
elseif t > 10 && t <= 20
    Fin = 10;
    Fout = 0;
elseif t> 20 && t <= 25
    Fout = 10;
    Fin = 10;
else
    Fout = 10;
    Fin = 5;
end
dy(1,:) = (Fin - Fout)/A;
A_exc =  Y(1)*D*3.14; % Calcolo area di scambio
dy(2,:) = 1/(A*Y(1))*(- U * A_exc * (Y(2) - Tamb)/(ro*cp) + Fin * (Tin -
Y(2)) + Fout * (Y(2) - Y(2)));
% NB se aggiungo Qin =  U * A_exc * (Y(2) - Tamb)/(ro*cp) la T rimane
% costante e pari a 60°C  ( Caso 3 )
end
```

Results


Temperature - Adiabatic system
Temperature [K]
Time [min]
334
333.5
333
332.5
332
0
10
20
30
40
50


Level - Adiabatic system
Level [m]
Time [min]
4.5
4
3.5
3
2.5
2
1.5
0
10
20
30
40
50


Temperature - NonAdiabatic system
Temperature [K]
Time [min]
333
332.9
332.8
332.7
332.6
332.5
332.4
0
10
20
30
40
50


Level - NonAdiabatic system
Level [m]
Time [min]
5
4
3
2
1
0
10
20
30
40
50