Pellet Smoker: Model B

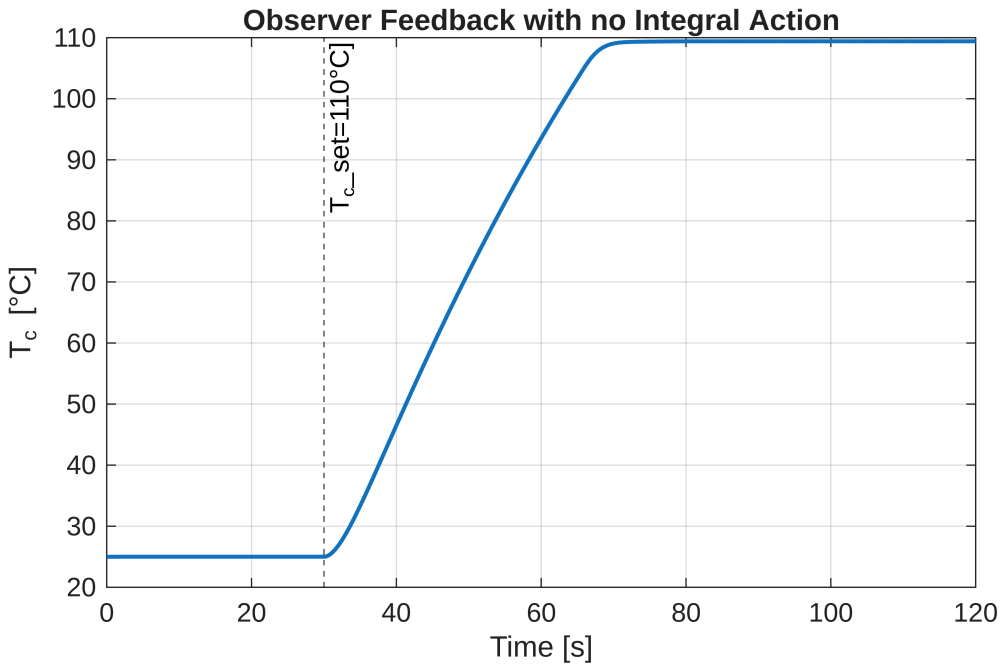
Set Particulars

```
p.C_f = 500;
p.k_f = 150;
p.k_ca = 25;
p.C_c = 2500;
p.k_fa = 20;
p.gamma = 1000;
p.T_amb = 25;
p.u_p_max = 10;
p.u_p_min = 0;
p.u_f_max = 1;
p.u_f_min = 0;
if false % uncertainty in model
    sigma = 0.20;
    p.C_f = 500*(1 + sigma * randn);
    p.k_f = 150*(1 + sigma * randn);
    p.k_ca = 25*(1 + sigma * randn);
    p.C_c = 2500*(1 + sigma * randn);
    p.k_fa = 20*(1 + sigma * randn);
    p.gamma = 1000*(1 + sigma * randn);
    p.T_amb = 25*(1 + sigma * randn);
end
```

Integral Action

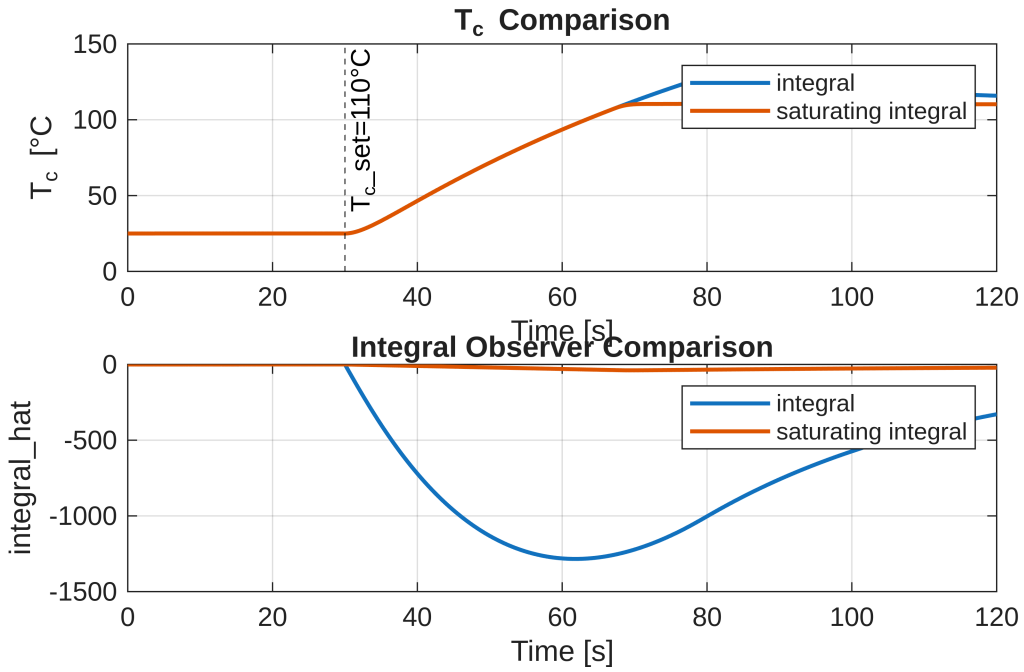
```
% initialization points
init_points.T_c_start = p.T_amb;
init_points.m_p_start = 10000;
% linearization and timeseries
lin_timeseries.t_min = 0;
lin_timeseries.t_max = 120;
lin_timeseries.lin = linearize(p, [0.4; 0.6]);
T_c_set_series = @(t) (t<=30)*p.T_amb+(t>30&&t<=600)*110+(t>1200)*130;
lin_timeseries.setpoint = @(t) [Tce2Tfe(p,T_c_set_series(t));
T_c_set_series(t); 0];
lin_timeseries.door_status = @(t) (t>=50)&&(t<20);

% Comparative simulations on integral action
[basic.t, basic.x_aug, basic.u] = run_simulation(p, init_points,
lin_timeseries, @basic_observer, @basic_feedback);
[int.t, int.x_aug, int.u] = run_simulation(p, init_points, lin_timeseries,
@integral_observer, @integral_feedback);
[sat.t, sat.x_aug, sat.u] = run_simulation(p, init_points, lin_timeseries,
@saturating_integral_observer, @integral_feedback);
```

```
figure;
plot(basic.t, basic.x_aug(2,:), 'LineWidth', 1.5); hold on;
xlabel('Time [s]');
ylabel(['T_c [' char(176) 'C]']);
title('Observer Feedback with no Integral Action');
grid on;
xline(30,  '--k', ['T_c\_set=110' char(176) 'C]'],
'LabelHorizontalAlignment','right');
```




```
% plot
figure;
title("Anti-Windup Integral Action vs Saturating Integral Action")
subplot(2,1,1);
plot(int.t,   int.x_aug(2,:),   'LineWidth', 1.5); hold on;
plot(sat.t,   sat.x_aug(2,:),   'LineWidth', 1.5);
xline(30,  '--k', ['T_c\_set=110' char(176) 'C'],
'LabelHorizontalAlignment','right');
hold off;
xlabel('Time [s]');
ylabel(['T_c [' char(176) 'C']);
title('T_c Comparison');
legend('integral', 'saturating integral');
grid on;
subplot(2,1,2);
plot(int.t, int.x_aug(7,:), 'LineWidth', 1.5); hold on;
plot(sat.t, sat.x_aug(7,:), 'LineWidth', 1.5);
hold off;
xlabel('Time [s]');
ylabel('integral\_hat');
title('Integral Observer Comparison');
```

```
legend('integral', 'saturating integral');
grid on;
```



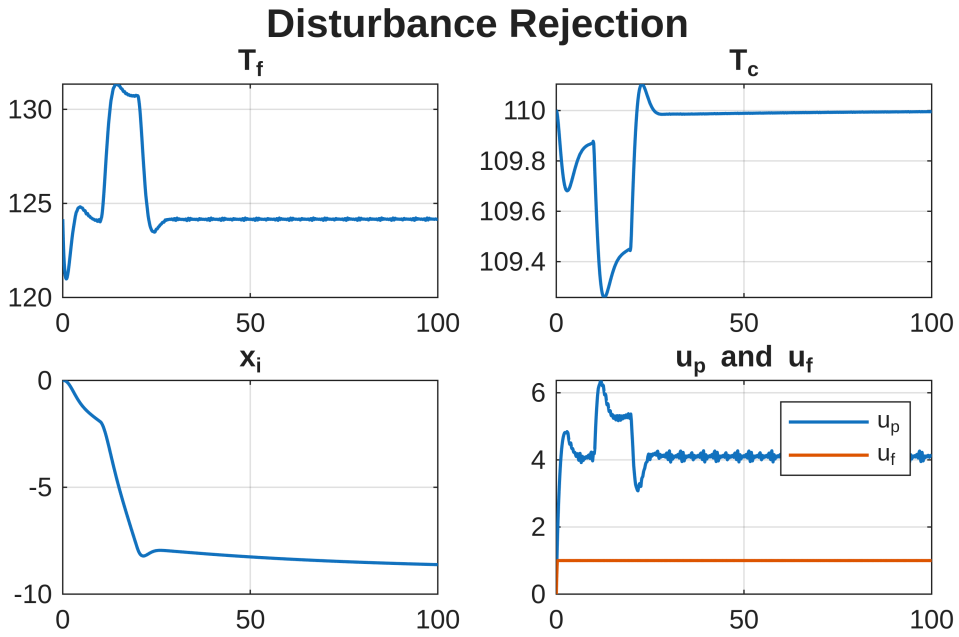
Disturbance Rejection

```
% initialization points
t_min = 0;
t_max = 100;
T_c_start = 110;
T_c_set = 110; % static setpoint. series setpoint also defined below
m_p_start = 10000;

% linearization and timeseries
lin = linearize(p, [0.4; 0.6]);
T_c_set_series = @(t) (t<=600)*110+(t>600&&t<1200)*110+(t>1200)*130;
setpoint = @(t) [Tce2Tfe(p,T_c_set_series(t)); T_c_set_series(t); 0];
door_status = @(t) (t>=10)&&(t<20);

% set up x_aug_0
x_0 = [Tce2Tfe(p, T_c_start); T_c_start; m_p_start];
x_hat_0 = [Tce2Tfe(p, T_c_start); T_c_start; m_p_start];
integral_hat_0 = 0;
u_hat_0 = [0; 0];
% definition
x_aug_0 = [x_0; x_hat_0; integral_hat_0];% u_hat_0];

% differential equation
x_dot_aug = @(t,x) full_differential_equation(x, @nonlinear_model,
@saturating_integral_observer, @integral_feedback, setpoint(t),
door_status(t), lin, p);
```

```
% use ode45 to solve differential equation
[t, result] = ode45(x_dot_aug, [t_min; t_max], x_aug_0);
result = result'; % get the results as column vector

% recover your u timeseries from x_hat
u = recover_u(@integral_feedback, linspace(t_min,t_max,size(result,2)),
result(4:6,:), result(7,:), setpoint, p, lin)
```

```
u = 2×669
         0    0.2534    0.4859    0.7003    0.8991    1.0844    1.2575    1.4199 ···
         0    0.1689    0.3240    0.4669    0.5994    0.7229    0.8384    0.9466
```

```
%x_hat, integral_hat, setpoint, p, lin

% plot!
plot_all(t, result, u, "Disturbance Rejection")
```



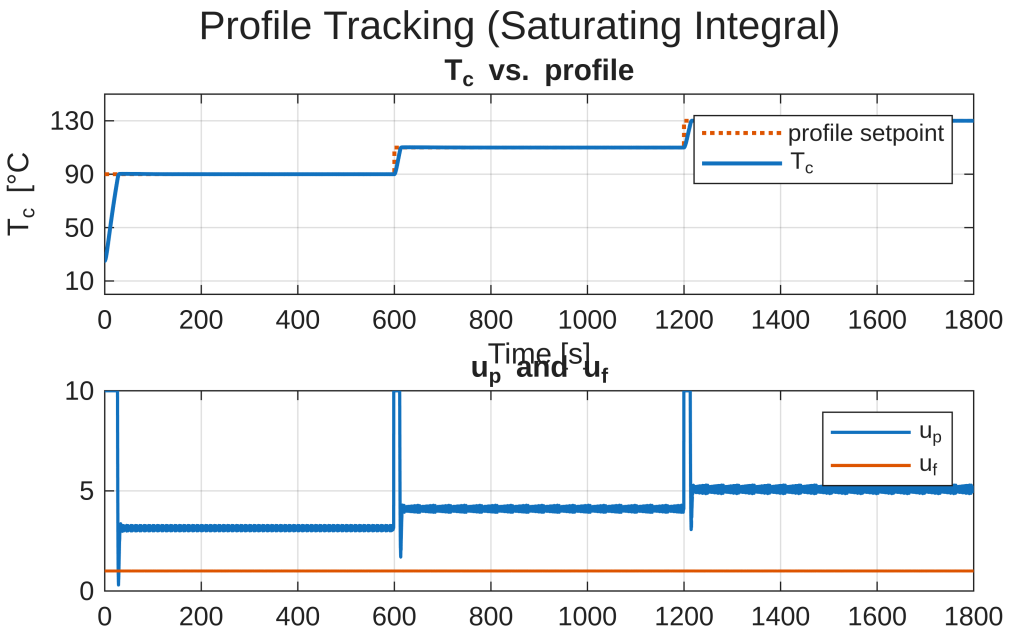
Profile Tracking

```
% initialization points
init_points.T_c_start = p.T_amb;
init_points.m_p_start = 10000;
% linearization and timeseries
lin_timeseries.t_min = 0;
lin_timeseries.t_max = 1800;
lin_timeseries.lin = linearize(p, [0.4; 0.6]);
T_c_set_series = @(t) (t<=600)*90+((t>600).*(t<=1200))*110+(t>1200)*130;
lin_timeseries.setpoint = @(t) [Tce2Tfe(p,T_c_set_series(t));
T_c_set_series(t); 0];
```

```
lin_timeseries.door_status = @(t) 0 % never
```

```
lin_timeseries = struct with fields:
             t_min: 0
             t_max: 1800
               lin: [1×1 struct]
    T_c_set_series: @(t)(t<=300)*p.T_amb+(t>60&&t<=120)*110+(t>1200)*130
          setpoint: @(t)[Tce2Tfe(p,T_c_set_series(t));T_c_set_series(t);0]
       door_status: @(t)0
```

```
% Comparative simulations on integral action
[sat.t, sat.x_aug, sat.u] = run_simulation(p, init_points, lin_timeseries,
@saturating_integral_observer, @integral_feedback);

% plot
figure;
sgtitle("Profile Tracking (Saturating Integral)")
subplot(2,1,1);
plot(sat.t,   sat.x_aug(2,:),   'LineWidth', 1.5); hold on;
set = T_c_set_series(sat.t);
h2 = plot(sat.t,set,   'LineWidth', 1.5, 'LineStyle', ':');
uistack(h2, 'bottom');
legend('profile setpoint', 'T_c')
hold off;
xlabel('Time [s]');
ylabel(['T_c [' char(176) 'C']);
title('T_c vs. profile');
yticks([10 50 90 130]);
xlim([0 1800])
grid on;
subplot(2,1,2);
plot(sat.t, sat.u(1,:), 'LineWidth', 1.2); hold on;
plot(sat.t, sat.u(2,:), 'LineWidth', 1.2);
title('u_p and u_f');
legend('u_p','u_f');
xlim([0 1800])
grid on;
```


Profile Tracking (Saturating Integral)
T_c vs. profile
T_c [°C]
130
90
50
10
0
200
400
600
800
1000
1200
1400
1600
1800
profile setpoint
T_c
Time [s]
u_p and u_f
10
5
0
u_p
u_f