Jacksa

```
clear
```

Definitions

Plunger

```
pl_d_out    =    17.5;     % mm
pl_d_hole   =    1;     % mm
pl_height   =    15.5;         % mm
pl_d_in     =    12;     % mm
pl_A_out    =    pl_d_out^2/4*pi;     % mm^2
pl_A_hole   =    pl_d_hole^2/4*pi     % mm^2
```

```
pl_A_hole = 0.7854
```

```
pl_A_in     =    pl_d_in^2/4*pi;     % mm^2
pl_A_u      =    pl_A_out - pl_A_in;     % mm^2
pl_m        =    0.012;  % kg
pl_rom      =    0.0059;  % m
```

Design Params

```
load('design_params.mat');
load('micro_hs_v_electromagnetic');
```

Volume

```
v_closed    =   3675;     % mm^3
v_open        =   2198;     % mm^3
```

Init arrays

```
%dt = 0.000001; % s
%T = 0.02/dt; % s
% t = zeros(T); % s
% P_ac = zeros(T); % bar
% T_ac = zeros(T); % K
% P_u = zeros(T); % bar
% T_u = zeros(T); % K
% P_d = zeros(T); % bar
% T_d = zeros(T); % K
% P_ups = zeros(T); % K
% T_ups = zeros(T); % K
% P_dps = zeros(T); % K
% T_dps = zeros(T); % K
%
% x = zeros(T); % m
% v = zeros(T); % m/s
% a = zeros(T); % m/s^2
%
```

```
% V_ac = zeros(T); % mm^3
%
% pilot = zeros(T); % 1 = open, 0 = closed
%
% A_m = zeros(T); % mm^2
%
% m_dot_u_ups = zeros(T); % kg/s
% m_dot_ups_ac = zeros(T); % kg/s
% m_dot_ac_dps = zeros(T); % kg/s
% m_dot_ups_dps = zeros(T); % kg/s
% m_dot_dps_d = zeros(T); % kg/s
%
% m_dot_ac_net = zeros(T); % kg/s
% m_dot_ups_net = zeros(T); % kg/s
% m_dot_dps_net = zeros(T); % kg/s
%
% F_ac = zeros(T); % N
% F_d = zeros(T); % N
% F_u = zeros(T); % N
% F_f = zeros(T); % N
% F_s = zeros(T); % N
% F = zeros(T); % N
%
% m_ac = zeros(T);
% m_ups = zeros(T);
% m_dps = zeros(T);
```

Test Case 1

- Infinite Upstream Volume @ 400 bar 273 K
- Pipe Section after upstream @ 400 bar 273 K
- Infinite Downstream Volume @ 1 bar 273 K
- Pipe Section before downstream @ 1 bar 273 K
- Outlet external orifice D = 2 mm
- Pilot closed @ t(0)
- P_ac = 400 bar @ t(0)
- Plunger displacement x = 0 @ t(0)

```
dt = 1e-7; % s
T = 0.1/dt; % s
gam = 1.4;
R = 296.8; % kJ/kgK
polythropic_index = gam ;

damper = 10; % kg/s

t(1) = 0; % s
P_ac(1) = 400; % bar
T_ac(1) = 273; % K
P_u(1) = 400; % bar
T_u(1) = 273; % K
```

```
P_d(1) = 1; % bar
T_d(1) = 273; % K
P_ups(1) = 400; % K
T_ups(1) = 273; % K
P_dps(1) = 1; % K
T_dps(1) = 273; % K

x(1) = 0; % m
v(1) = 0; % m/s
a(1) = 0; % m/s^2

V_ac(1) = v_closed; % mm^3

pilot(1) = 0; % 1 = open, 0 = closed

A_m(1) = o_d_in * pi * x(1) * 10^-3; % mm^2

m_dot_u_ups(1) = 0; % kg/s
m_dot_ups_ac(1) = 0; % kg/s
m_dot_ac_dps(1) = 0; % kg/s
m_dot_ups_dps(1) = 0; % kg/s
m_dot_dps_d(1) = 0; % kg/s

m_dot_ac_net(1) = 0; % kg/s
m_dot_ups_net(1) = 0; % kg/s
m_dot_dps_net(1) = 0; % kg/s

F_ac(1) = B_to_Pa(P_ac(1)) * pl_A_out * 10^-6; % N
F_d(1) = B_to_Pa(P_dps(1)) * pl_A_in * 10^-6; % N
F_u(1) = B_to_Pa(P_ups(1)) * pl_A_u * 10^-6; % N
F_f(1) = - damper * v(1); % N
F_s(1) = 500; % N
F(1) = - F_ac(1) + F_d(1) + F_u(1) + F_f(1) - F_s(1); % N

m_ac(1) = 0.014 * B_to_Pa(P_ac(1)) * v_closed * 10^-9 / (T_ac(1) * R);
m_ups(1) = 0.014 * B_to_Pa(P_ups(1)) * V_ups * 10^-9 / (T_ups(1) * R);
m_dps(1) = 0.014 * B_to_Pa(P_dps(1)) * V_dps * 10^-9 / (T_dps(1) * R);


px(1) = 0; % m
pv(1) = 0; % m/s
pa(1) = 0; % m/s^2

%%pilot_pressure_surface = pi * (dynamic.valve.valve_seat_outlet_orifice_rad +...
%%    dynamic.valve.valve_seat_outlet_orifice_d/2)^2; %mm^2

pilot_pressure_surface = pi * (0.25 +...
    dynamic.valve.valve_seat_outlet_orifice_d/2)^2; %mm^2

Fmag(1) = 0;
F_p_p(1) = -B_to_Pa(P_ac(1)-P_dps(1)) * pilot_pressure_surface * 10^-6; % N
K = 30e3 % N/m
```

```
K = 30000
```

```
F_p_s(1) = -(px(1) + 0.25e-3) * K;
F_p(1) = Fmag(1) + F_p_p(1) + F_p_s(1);
V_L(1) = dynamic.V; % V
pl_A_hole(1) = 0; %m^2
pl_A_hole_max = 0.25 * pi * dynamic.valve.valve_seat_outlet_orifice_d^2 * 1e-6 %m^2
```

```
pl_A_hole_max = 1.9635e-07
```

```
A_adj * 1e-6
```

```
ans = 7.0686e-08
```

```

for i = 2:(T-1)
    t(i) = t(i-1) + dt; % s

    signal(i) = i < (0.5*T); % 1 = open, 0 = closed

    % Magnetism
    if (signal(i) > 0)
        V_L(i) = dynamic.V * exp(-t(i)/dynamic.tao);
        I(i) = dynamic.V/dynamic.R *(1 - exp(-t(i)/dynamic.tao)) * 1e3;
    else
        V_L(i) = - dynamic.V * exp(-(t(i)-0.5*T*dt)/dynamic.tao);
        I(i) = dynamic.V/dynamic.R *exp(-(t(i)-0.5*T*dt)/dynamic.tao) * 1e3;
    end
    [Fmag(i),N,wire_len,wire_R,sol_V(i),sol_P(i),L(i)] =...
        valve_magnetic_force(dynamic.valve,dynamic.valve.rom,I(i)*1e-3);

    F_p_s(i) = -(px(i-1) + 0.25e-3) * K;
    F_p_p(i) = -B_to_Pa(P_ac(i-1)-P_dps(i-1)) * pilot_pressure_surface * 10^-6; % N
    F_p(i) = Fmag(i) + F_p_p(i) + F_p_s(i);

    % Calculate displacement from previous forces
    px(i) = px(i-1) + pv(i-1)*dt + 0.5*pa(i-1)*dt^2; % m
    pv(i) = pv(i-1) + pa(i-1)*dt; % m/s
    pa(i) = F_p(i) / (dynamic.spring_rod_m+dynamic.valve_spool_m); % m/s^2
    if px(i) < 0
        px(i) = 0; % m
        pv(i) = 0; % m/s
        pa(i) = 0; % m/s^2
    elseif px(i) > dynamic.valve.rom * 1e-3
        px(i) = dynamic.valve.rom * 1e-3; % m
        pv(i) = 0; % m/s
        pa(i) = 0; % m/s^2
    end

    % Calculate Pilot area with new displacement
    pl_A_hole(i) = dynamic.valve.valve_seat_outlet_d * pi * px(i) * 10^-3; % m^2
    if pl_A_hole(i) > pl_A_hole_max
        pl_A_hole(i) = pl_A_hole_max;
    end

    pilot(i) = pl_A_hole(i) > 0; % 1 = open, 0 = closed
```

```
% FluidMechanics
P_u(i) = P_u(i-1); % bar
T_u(i) = T_u(i-1); % K
P_d(i) = P_d(i-1); % bar
T_d(i) = T_d(i-1); % K

% Calculate forces
F_ac(i) = B_to_Pa(P_ac(i-1)) * pl_A_out * 10^-6; % N
F_d(i) = B_to_Pa(P_dps(i-1)) * pl_A_in * 10^-6; % N
F_u(i) = B_to_Pa(P_ups(i-1)) * pl_A_u * 10^-6; % N
F_f(i) = - damper * v(i-1); % N
F_s(i) = F_s(1); % N
F(i) = - F_ac(i) + F_d(i) + F_u(i) + F_f(i) - F_s(i); % N

% Calculate displacement from previous forces
x(i) = x(i-1) + v(i-1)*dt + 0.5*a(i-1)*dt^2; % m
v(i) = v(i-1) + a(i-1)*dt; % m/s
a(i) = F(i) / pl_m; % m/s^2
if x(i) < 0
    x(i) = 0; % m
    v(i) = 0; % m/s
    a(i) = 0; % m/s^2
elseif x(i) > pl_rom
    x(i) = pl_rom; % m
    v(i) = 0; % m/s
    a(i) = 0; % m/s^2
end

% Calculate Main area with new displacement
A_m(i) = o_d_in * pi * x(i) * 10^-3; % m^2
if A_m(i) > o_A_in
    A_m(i) = o_A_in;
end

% Calculate Actuation Chamber Volume after displacement
V_ac(i) = (pl_rom - x(i)) * (v_closed - v_open) / pl_rom + v_open; % mm^3

% Isentropic Compression
P_ac(i) = P_ac(i-1) * (V_ac(i-1)/V_ac(i))^polythropic_index; % Bar
T_ac(i) = T_ac(i-1) * (P_ac(i)/P_ac(i-1))^(1-1/polythropic_index); % K

% Actuation Chamber Volume / Actuation Chamber related
m_dot_ups_ac(i) = mdot_orifice(...
    P_ups(i-1),P_ac(i) ,polythropic_index,A_adj    *10^-6,T_ups(i-1),R); % kg/s
m_dot_ac_dps(i) = mdot_orifice(...
    P_ac(i), P_dps(i-1),polythropic_index,pl_A_hole(i),T_ac(i), R) * (pilot(i)==1)

[P_ac(i), T_ac(i), m_ac(i)] = tank_discharge_P_io(P_ac(i),T_ac(i),m_ac(i-1),...
     [T_ups(i-1),       T_ac(i-1)],...
     [m_dot_ups_ac(i),  - m_dot_ac_dps(i)] * dt,...
     polythropic_index); % bar, K

m_dot_ac_net(i) = m_ac(i) - m_ac(i-1); % kg/s
```

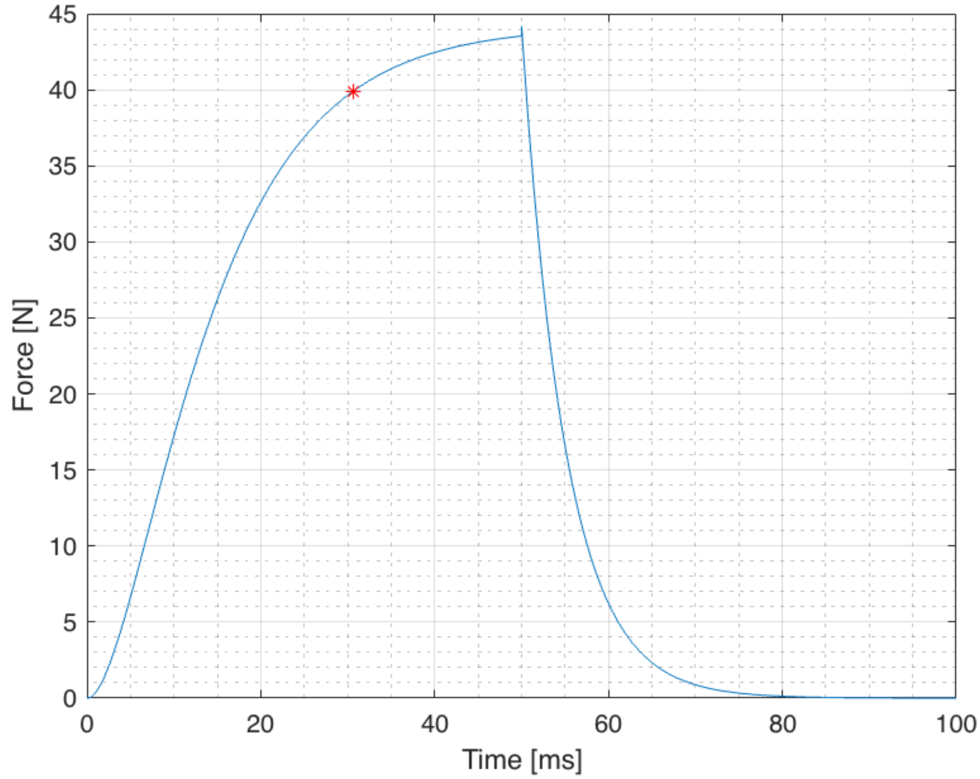
```
    % Pipe Section Upstream related
    m_dot_ups_dps(i) = mdot_orifice(P_ups(i-1),P_dps(i-1),polythropic_index,A_m(i),T_up
    m_dot_u_ups(i) = mdot_orifice(P_u(i-1),  P_ups(i-1),polythropic_index,io_A    *10^-

    [P_ups(i), T_ups(i), m_ups(i)] = tank_discharge_P_io(P_ups(i-1),T_ups(i-1),m_ups(i-
         [T_u(i-1),        T_ups(i-1),          T_ups(i-1)],...
         [m_dot_u_ups(i),  - m_dot_ups_ac(i),   - m_dot_ups_dps(i)] * dt,...
         polythropic_index); % bar, K

    m_dot_ups_net(i) = m_ups(i) - m_ups(i-1); % kg/s

    % Pipe Section Upstream related
    m_dot_dps_d(i) = mdot_orifice(P_dps(i-1),P_d(i-1)  ,polythropic_index,oe_o_A    *10
    m_dot_dps_net(i) = m_dot_ac_dps(i) - m_dot_dps_d(i) + m_dot_ups_dps(i); % kg/s
    m_dps(i) = m_dps(i-1) + m_dot_dps_net(i) * dt; % kg
    [P_dps(i), T_dps(i)] = tank_discharge_P(P_dps(i-1),T_dps(i-1),m_dps(i-1),...
         - m_dot_dps_net(i) * dt,polythropic_index); % bar, K

    [P_dps(i), T_dps(i), m_dps(i)] = tank_discharge_P_io(P_dps(i-1),T_dps(i-1),m_dps(i-
         [T_dps(i-1),        T_ac(i-1),         T_ups(i-1)],...
         [-m_dot_dps_d(i), m_dot_ac_dps(i),   m_dot_ups_dps(i)] * dt,...
         polythropic_index); % bar, K

    m_dot_dps_net(i) = m_dps(i) - m_dps(i-1); % kg/s
end

try
    tao3index = ceil(3*dynamic.tao/dt);
    t(tao3index)
catch
    tao3index = 1;
end
```

```
ans = 0.0306
```

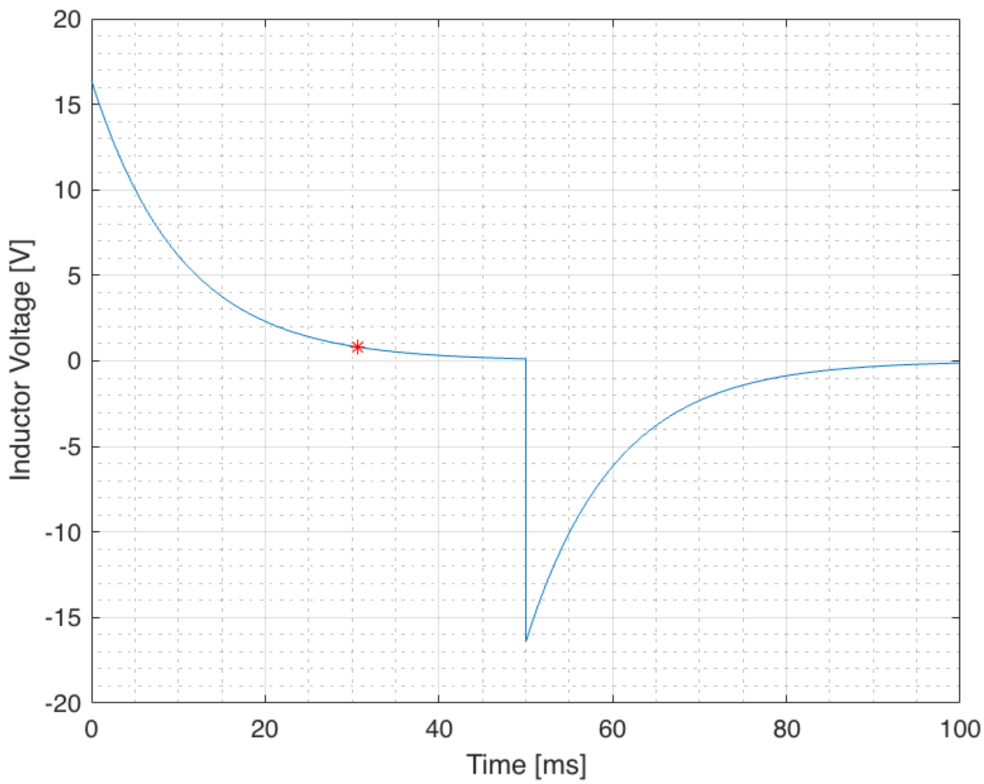
Results

```
if true
    figure
    plot(t*1e3,Fmag,t(tao3index)*1e3,Fmag(tao3index),'r*'), xlabel('Time [ms]'), ylabel
    figure
    plot(t*1e3,V_L,t(tao3index)*1e3,V_L(tao3index),'r*'), xlabel('Time [ms]'), ylabel(
    figure
    plot(t*1e3,I,t(tao3index)*1e3,I(tao3index),'r*'), xlabel('Time [ms]'), ylabel('Cur
    figure
    plot(t,Fmag,t,F_p_p,t,F_p_s,t,F_p)
    grid on, grid minor, xlabel('Time [s]'), ylabel('Force [N]'), title('Forces On Pilo
    legend('Mag','Pres','Spring','Net')
    figure
    subplot(2,1,1)
    plot(t,px)
    grid on, grid minor, xlabel('Time [s]'), ylabel('Displacement [m]'), title('Pilot P
    subplot(2,1,2)
```

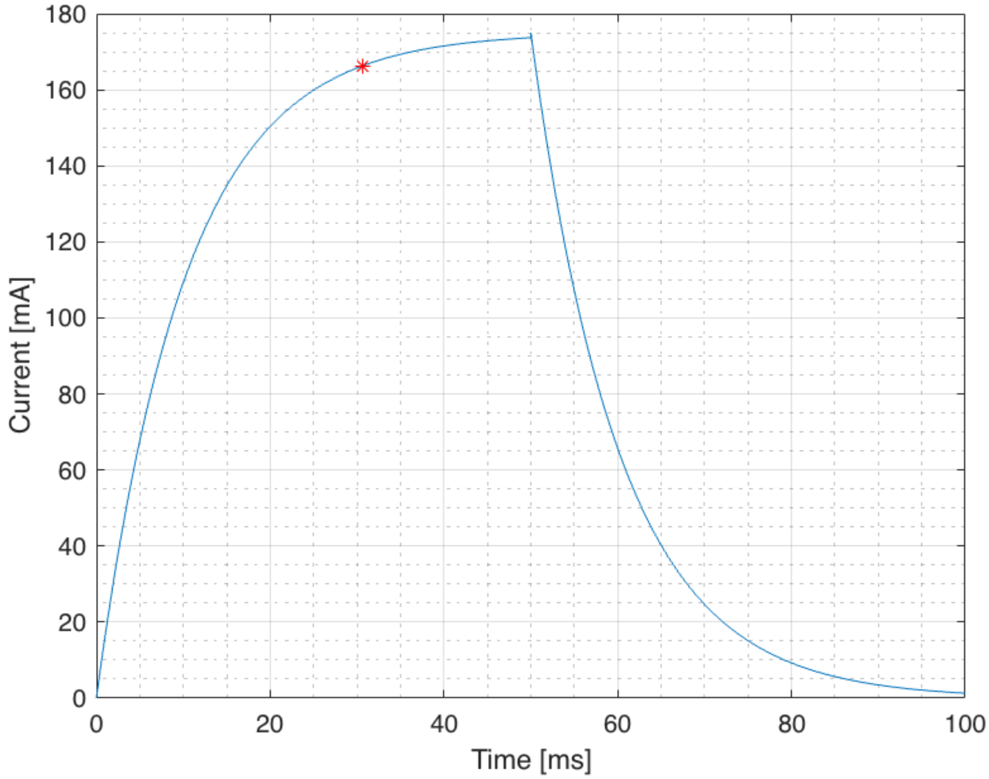
```
    plot(t,pv)
    grid on, grid minor, xlabel('Time [s]'), ylabel('Velocity [m/s]'), title('Pilot Ve
    figure
    plot(t,m_dot_ups_ac,t,m_dot_ac_dps,t,m_dot_ac_net)
    grid on, grid minor, xlabel('Time [s]'), ylabel('M dot [kg/s]'), title('M dot')
    legend('U to AC', 'AC to D', 'AC net')
    figure
    plot(t,P_u,t,P_ac,t,P_d,t,P_dps,t,P_ups)
    grid on, grid minor, xlabel('Time [s]'), ylabel('Pressure [Bar]'), title('Pressure
    legend('U','AC','D','DPS','UPS')
    figure
    subplot(3,1,1)
    plot(t,x)
    grid on, grid minor, xlabel('Time [s]'), ylabel('Displacement [m]'), title('Plunge
    subplot(3,1,2)
    plot(t,V_ac)
    grid on, grid minor, xlabel('Time [s]'), ylabel('Volume [mm^3]'), title('Actuation
    subplot(3,1,3)
    plot(t,v)
    grid on, grid minor, xlabel('Time [s]'), ylabel('Velocity [m/s]'), title('Plunger 
    figure
    plot(t,F_ac,t,F_u,t,F_d,t,F)
    grid on, grid minor, xlabel('Time [s]'), ylabel('Force [N]'), title('Forces On Plu
    legend('AC','U','D','Net')
    figure
    plot(t,m_dot_ups_dps,t,m_dot_ac_dps,t,m_dot_dps_d,t,m_dot_dps_net)
    grid on, grid minor, xlabel('Time [s]'), ylabel('M dot [kg/s]'), title('DPS M dot'
    legend('UPS to DPS', 'AC to DPS', 'DPS to D', 'PDS net')
    figure
    plot(t,m_dot_u_ups,t,m_dot_ups_ac,t,m_dot_ups_dps,t,m_dot_ups_net)
    grid on, grid minor, xlabel('Time [s]'), ylabel('M dot [kg/s]'), title('UPS M dot'
    legend('U to UPS', 'UPS to AC', 'UPS to DPS', 'UPS net')
    figure
    plot(t,m_ups,t,m_dps,t,m_ac)
    grid on, grid minor, xlabel('Time [s]'), ylabel('Mass [kg]'), title('Volume masses
    legend('UPS', 'DPS', 'AC')
    figure
    plot(t,P_dps)
    grid on, grid minor, xlabel('Time [s]'), ylabel('Pressure [Bar]'), title('DPS Pres
    figure
    plotyy(t,m_dot_dps_d,t,P_dps),legend('m_dot_dps_d','P_dps')
    figure
    plotyy(t,m_dot_u_ups,t,P_ups),legend('m_dot_dps_d','P_dps'),title('UPS'),legend('m
    figure
    plot(t,T_u,t,T_ac,t,T_d,t,T_dps,t,T_ups)
    grid on, grid minor, xlabel('Time [s]'), ylabel('Temperature [K]'), title('Tempera
    legend('U','AC','D','DPS','UPS')
end
```



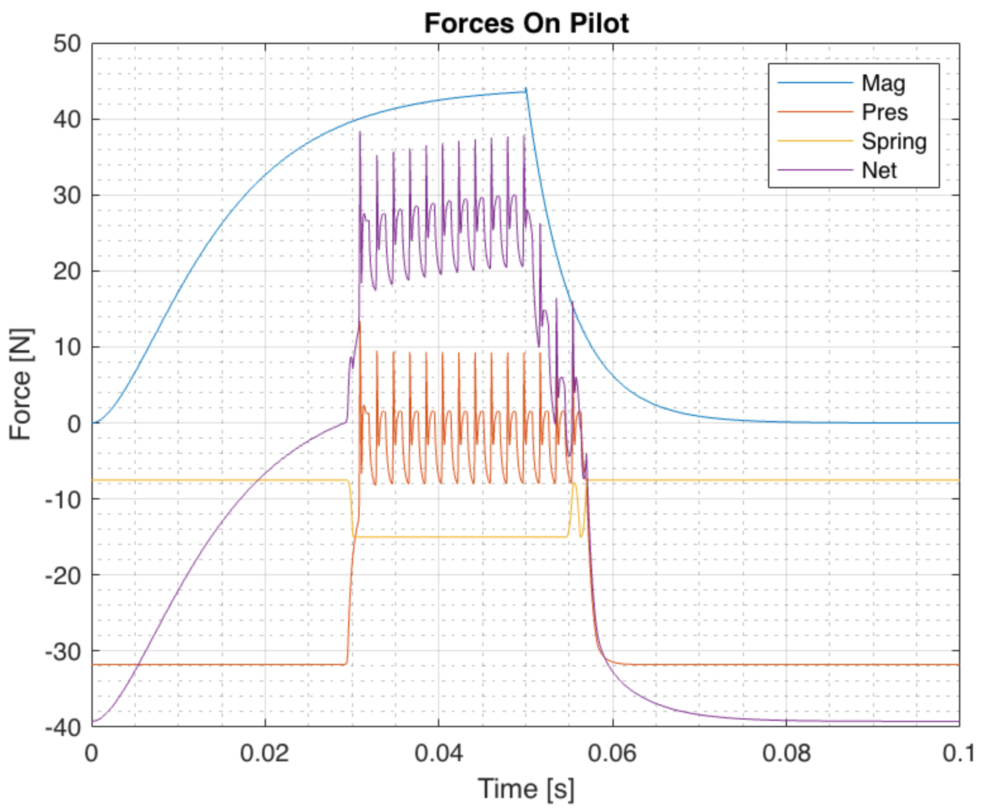
Force [N]
Time [ms]



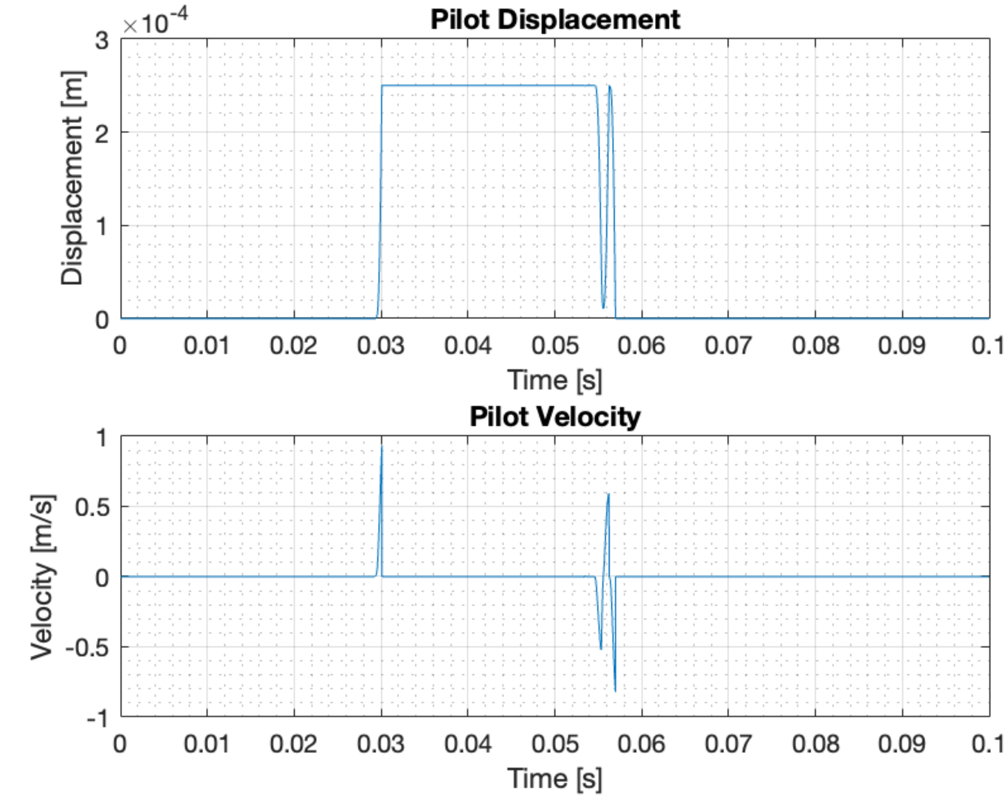
Inductor Voltage [V]
Time [ms]



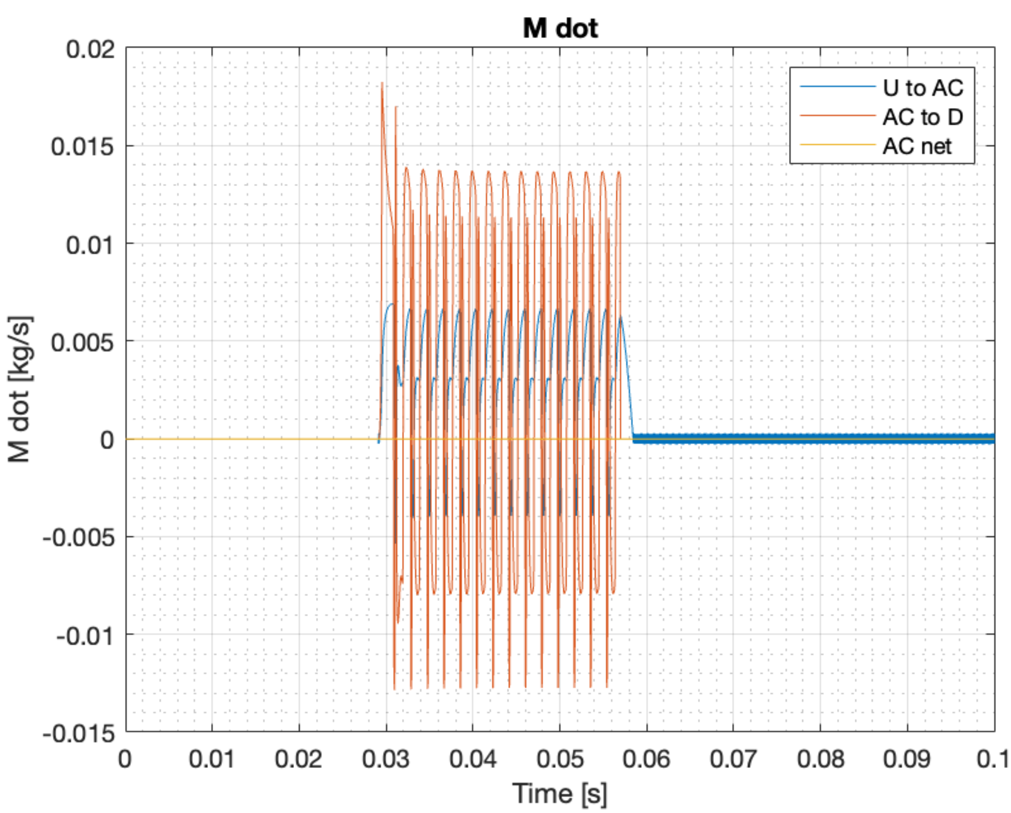
Current [mA]
Time [ms]



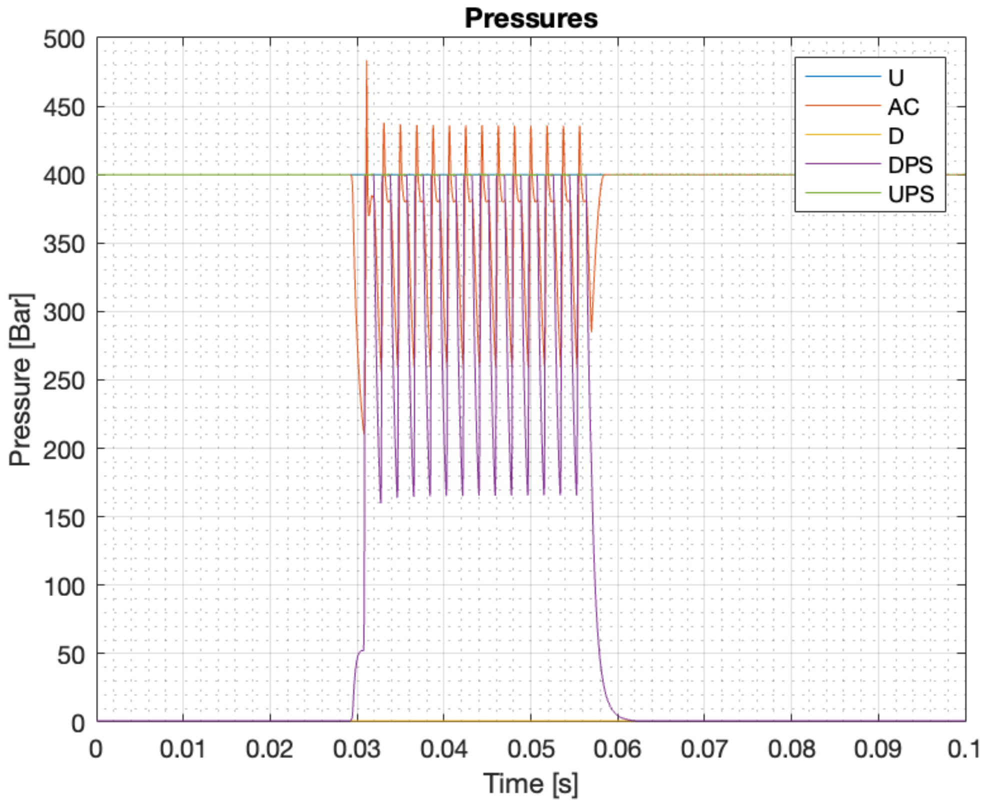
Forces On Pilot
Mag
Pres
Spring
Net
Force [N]
Time [s]



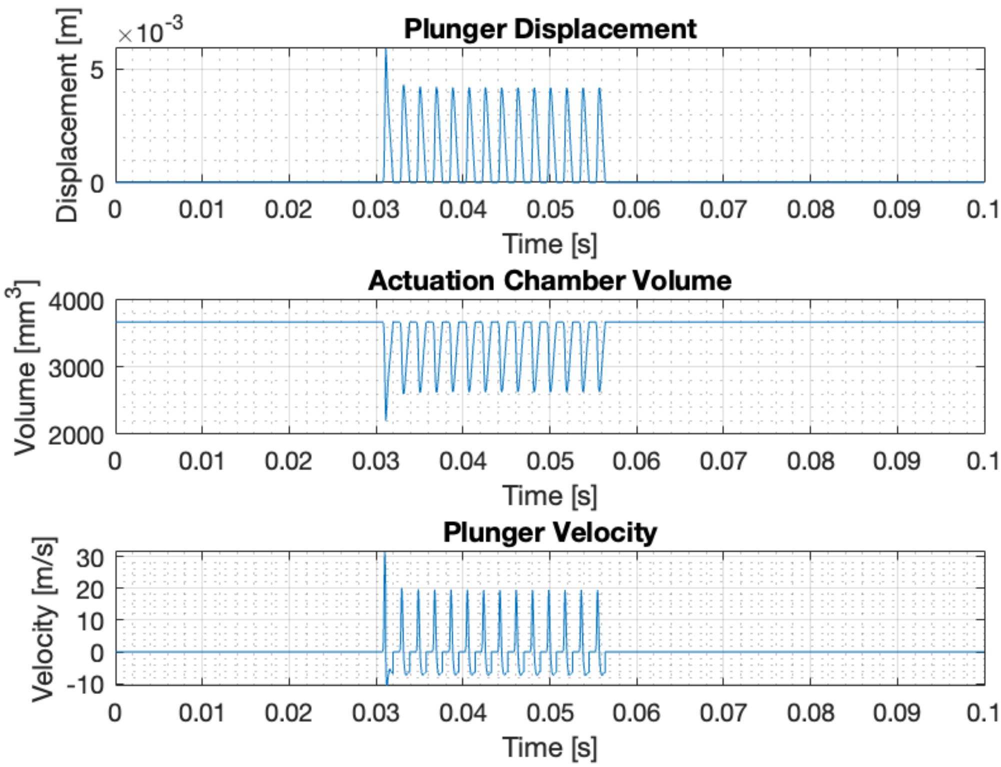
Pilot Displacement
×10^-4
Displacement [m]
Time [s]
Pilot Velocity
Velocity [m/s]
Time [s]



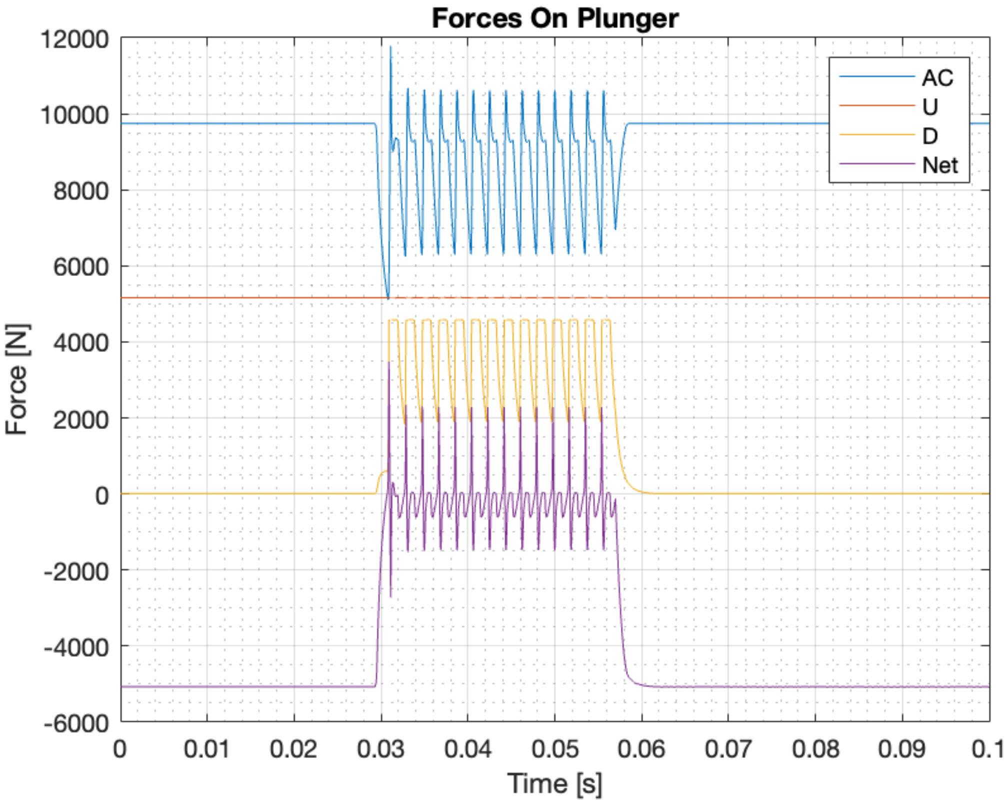
M dot
M dot [kg/s]
Time [s]
U to AC
AC to D
AC net

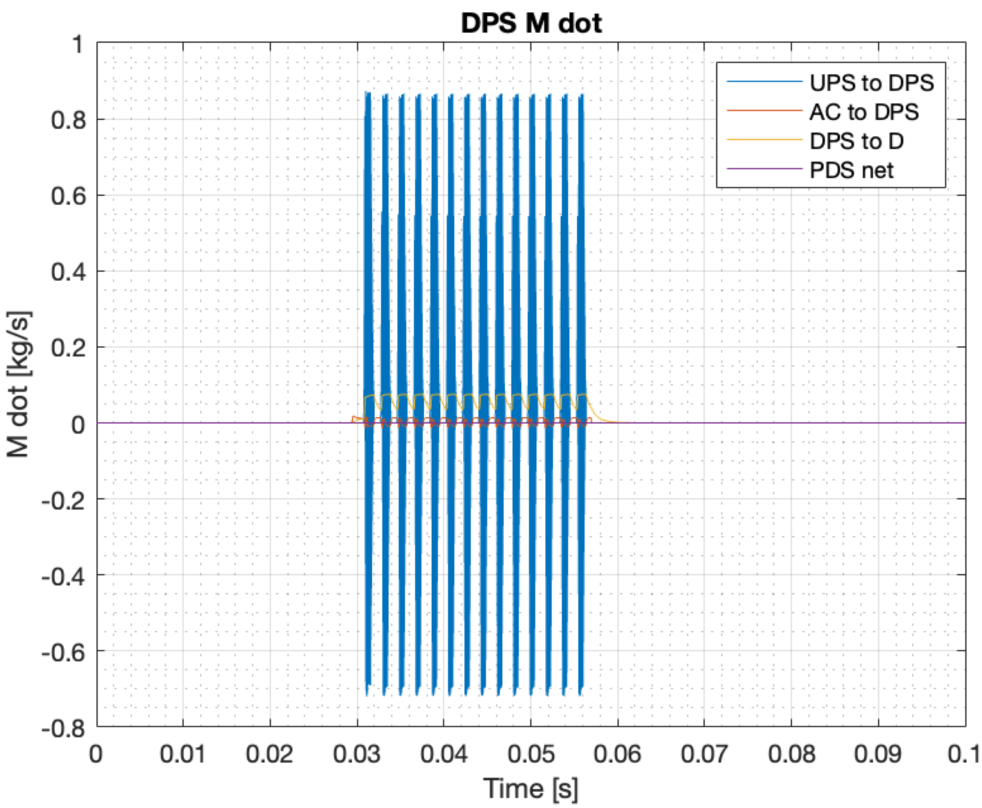


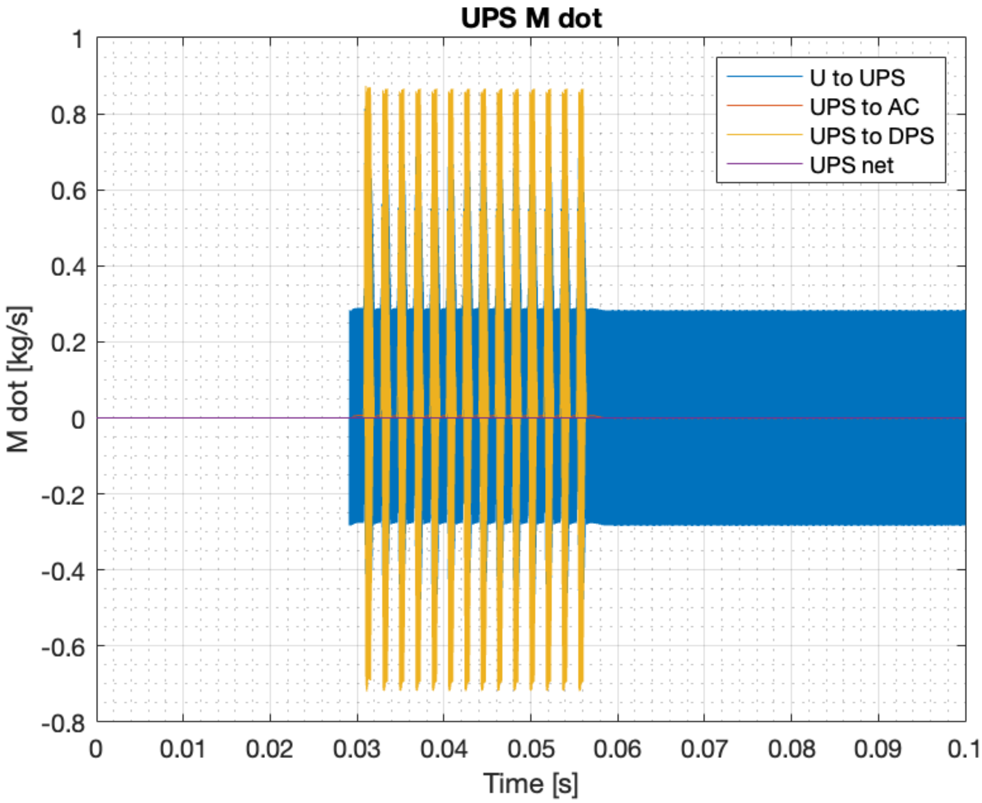
Pressures
Pressure [Bar]
Time [s]
U
AC
D
DPS
UPS

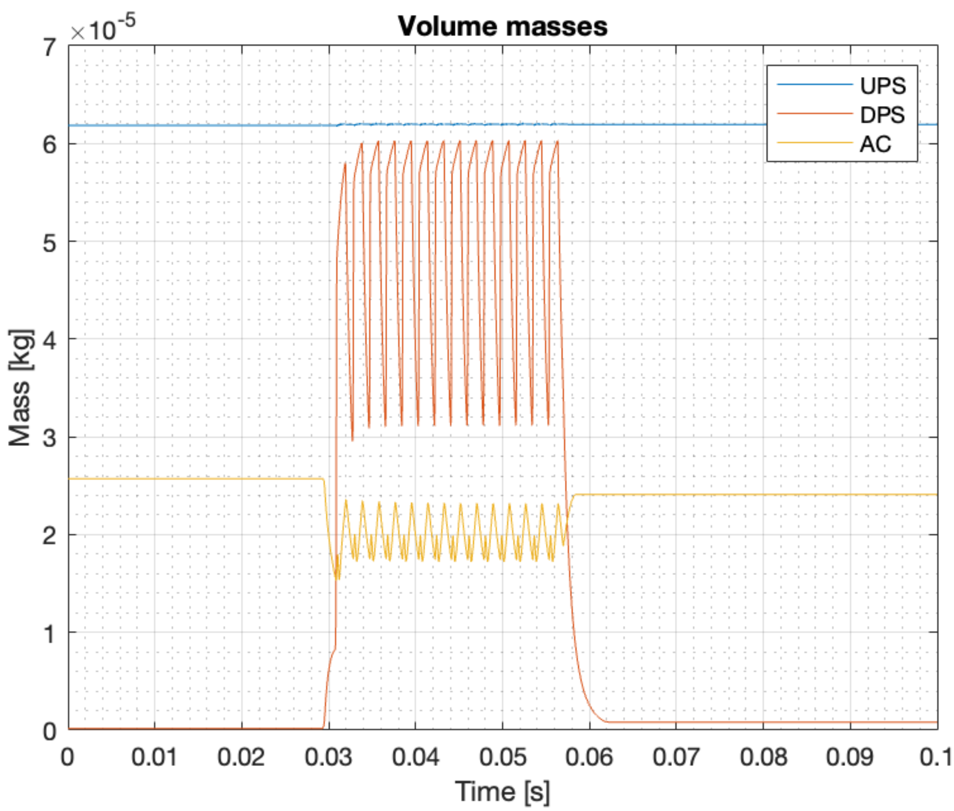


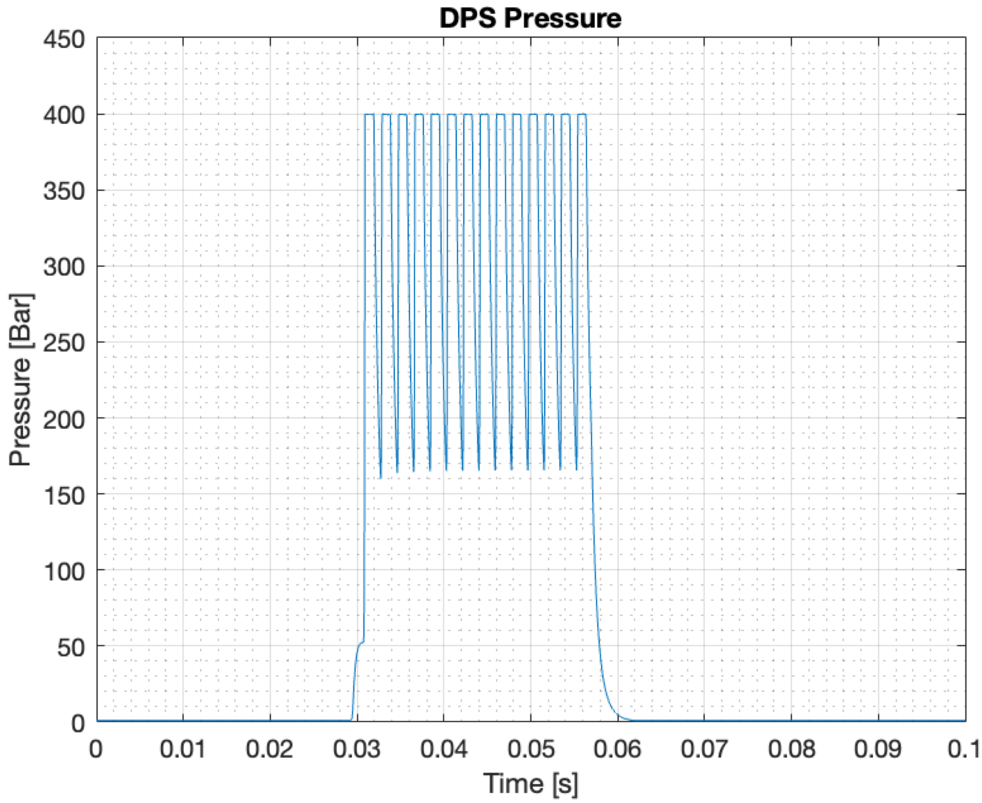
Plunger Displacement
Displacement [m]
Time [s]
Actuation Chamber Volume
Volume [mm^3]
Time [s]
Plunger Velocity
Velocity [m/s]
Time [s]

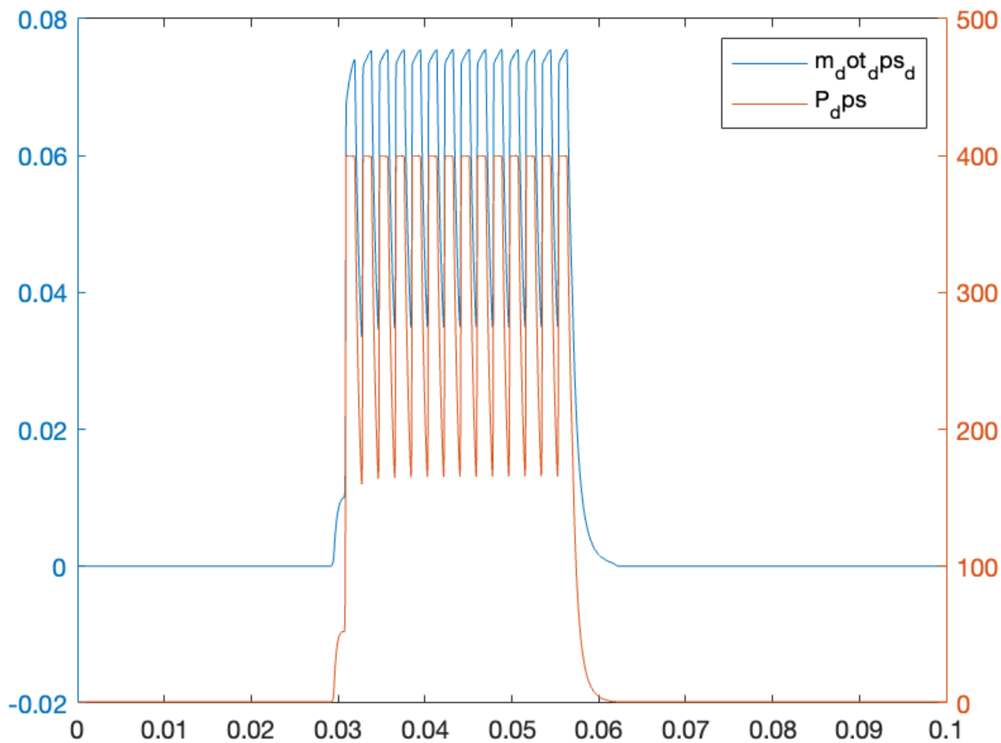

Forces On Plunger
AC
U
D
Net
Force [N]
Time [s]
12000
10000
8000
6000
4000
2000
0
-2000
-4000
-6000
0
0.01
0.02
0.03
0.04
0.05
0.06
0.07
0.08
0.09
0.1

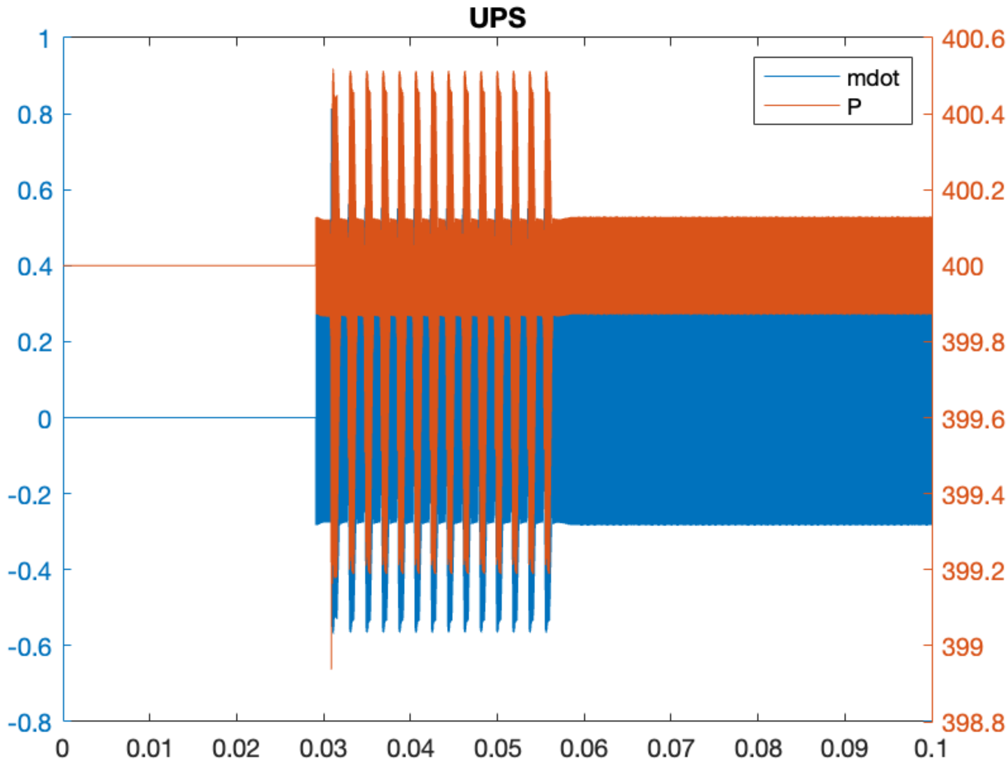

DPS M dot
UPS to DPS
AC to DPS
DPS to D
PDS net
M dot [kg/s]
Time [s]
1
0.8
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
-0.8
0
0.01
0.02
0.03
0.04
0.05
0.06
0.07
0.08
0.09
0.1

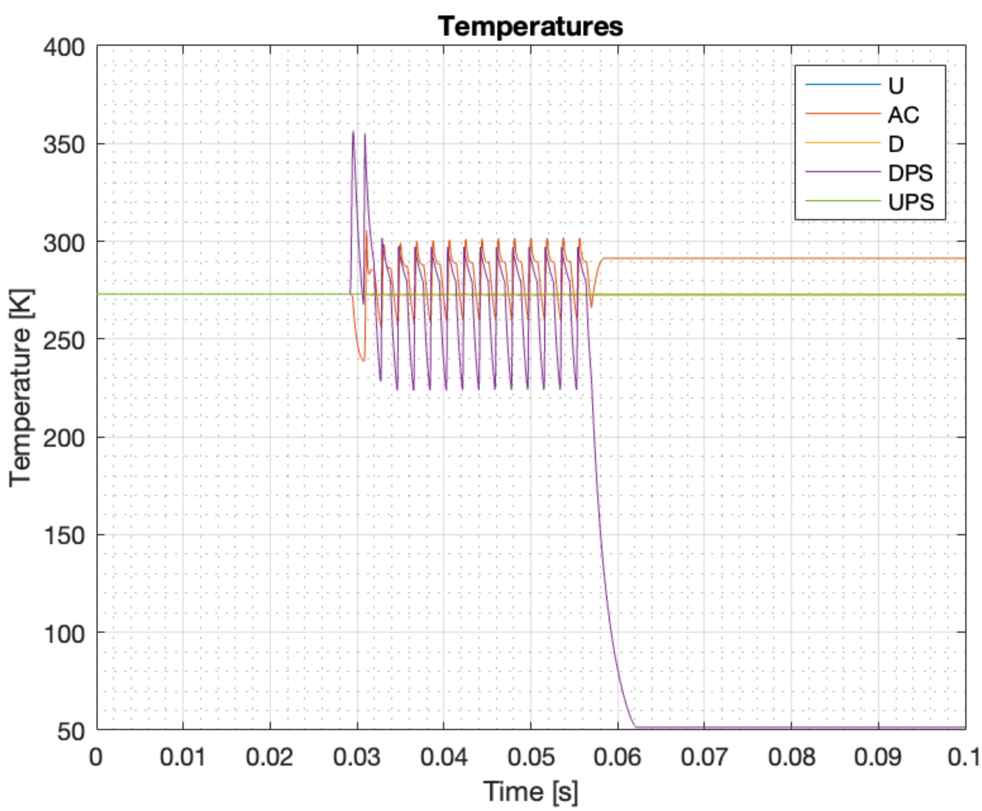

UPS M dot
U to UPS
UPS to AC
UPS to DPS
UPS net
M dot [kg/s]
Time [s]


Volume masses
$\times 10^{-5}$
UPS
DPS
AC
Mass [kg]
Time [s]


DPS Pressure
Pressure [Bar]
Time [s]
450
400
350
300
250
200
150
100
50
0
0
0.01
0.02
0.03
0.04
0.05
0.06
0.07
0.08
0.09
0.1


m_dot_dps_d
P_dps
0.08
0.06
0.04
0.02
0
-0.02
500
400
300
200
100
0
0
0.01
0.02
0.03
0.04
0.05
0.06
0.07
0.08
0.09
0.1






```
save('micro_hs_v_open_close')
```

Test Case 2

- Infinite Upstream Volume @ 400 bar 273 K
- Pipe Section after upstream @ 1 bar 273 K
- Infinite Downstream Volume @ 1 bar 273 K
- Pipe Section before downstream @ 1 bar 273 K
- Outlet external orifice D = 2 mm
- Pilot closed @ t(0)
- P_ac = 1 bar @ t(0)
- Plunger displacement x = 0 @ t(0)

```
dt = 0.000001; % s
T = 0.03/dt; % s
gam = 1.4;
R = 296.8; % kJ/kgK
polythropic_index = gam ;

damper = 1000; % kg/s

t(1) = 0; % s
P_ac(1) = 1; % bar
T_ac(1) = 273; % K
P_u(1) = 400; % bar
T_u(1) = 273; % K
P_d(1) = 1; % bar
T_d(1) = 273; % K
P_ups(1) = 1; % K
T_ups(1) = 273; % K
P_dps(1) = 1; % K
T_dps(1) = 273; % K

x(1) = 0; % m
v(1) = 0; % m/s
a(1) = 0; % m/s^2

V_ac(1) = v_closed; % mm^3

pilot(1) = 0; % 1 = open, 0 = closed

A_m(1) = o_d_in * pi * x(1) * 10^-3; % mm^2

m_dot_u_ups(1) = 0; % kg/s
m_dot_ups_ac(1) = 0; % kg/s
m_dot_ac_dps(1) = 0; % kg/s
m_dot_ups_dps(1) = 0; % kg/s
m_dot_dps_d(1) = 0; % kg/s

m_dot_ac_net(1) = 0; % kg/s
m_dot_ups_net(1) = 0; % kg/s
m_dot_dps_net(1) = 0; % kg/s

F_ac(1) = B_to_Pa(P_ac(1)) * pl_A_out * 10^-6; % N
```

```
F_d(1) = B_to_Pa(P_dps(1)) * pl_A_in * 10^-6; % N
F_u(1) = B_to_Pa(P_ups(1)) * pl_A_u * 10^-6; % N
F_f(1) = - damper * v(1); % N
F_s(1) = 500; % N
F(1) = - F_ac(1) + F_d(1) + F_u(1) + F_f(1) - F_s(1); % N

m_ac(1) = 0.014 * B_to_Pa(P_ac(1)) * v_closed * 10^-9 / (T_ac(1) * R);
m_ups(1) = 0.014 * B_to_Pa(P_ups(1)) * V_ups * 10^-9 / (T_ups(1) * R);
m_dps(1) = 0.014 * B_to_Pa(P_dps(1)) * V_dps * 10^-9 / (T_dps(1) * R);

for i = 2:(T-1)
    t(i) = t(i-1) + dt; % s
    pilot(i) = (i > (0.333*T)) & (i < (0.666*T)); % 1 = open, 0 = closed

    P_u(i) = P_u(i-1); % bar
    T_u(i) = T_u(i-1); % K
    P_d(i) = P_d(i-1); % bar
    T_d(i) = T_d(i-1); % K

    % Calculate forces
    F_ac(i) = B_to_Pa(P_ac(i-1)) * pl_A_out * 10^-6; % N
    F_d(i) = B_to_Pa(P_dps(i-1)) * pl_A_in * 10^-6; % N
    F_u(i) = B_to_Pa(P_ups(i-1)) * pl_A_u * 10^-6; % N
    F_f(i) = - damper * v(i-1); % N
    F_s(i) = F_s(1); % N
    F(i) = - F_ac(i) + F_d(i) + F_u(i) + F_f(i) - F_s(i); % N

    % Calculate displacement from previous forces
    x(i) = x(i-1) + v(i-1)*dt + 0.5*a(i-1)*dt^2; % m
    v(i) = v(i-1) + a(i-1)*dt; % m/s
    a(i) = F(i) / pl_m; % m/s^2
    if x(i) < 0
        x(i) = 0; % m
        v(i) = 0; % m/s
        a(i) = 0; % m/s^2
    elseif x(i) > pl_rom
        x(i) = pl_rom; % m
        v(i) = 0; % m/s
        a(i) = 0; % m/s^2
    end

    % Calculate Main area with new displacement
    A_m(i) = o_d_in * pi * x(i) * 10^-3; % m^2
    if A_m(i) > o_A_in
        A_m(i) = o_A_in;
    end

    % Calculate Actuation Chamber Volume after displacement
    V_ac(i) = (pl_rom - x(i)) * (v_closed - v_open) / pl_rom + v_open; % mm^3

    % Isentropic Compression
    P_ac(i) = P_ac(i-1) * (V_ac(i-1)/V_ac(i))^polythropic_index; % Bar
    T_ac(i) = T_ac(i-1) * (P_ac(i)/P_ac(i-1))^(1-1/polythropic_index); % K
```

```
    % Actuation Chamber Volume / Actuation Chamber related
    m_dot_ups_ac(i) = mdot_orifice(...
        P_ups(i-1),P_ac(i) ,polythropic_index,A_adj    *10^-6,T_ups(i-1),R); % kg/s
    m_dot_ac_dps(i) = mdot_orifice(...
        P_ac(i), P_dps(i-1),polythropic_index,pl_A_hole(i),T_ac(i), R) * (pilot(i)==1)

    [P_ac(i), T_ac(i), m_ac(i)] = tank_discharge_P_io(P_ac(i),T_ac(i),m_ac(i-1),...
         [T_ups(i-1),       T_ac(i-1)],...
         [m_dot_ups_ac(i),  - m_dot_ac_dps(i)] * dt,...
         polythropic_index); % bar, K

    m_dot_ac_net(i) = m_ac(i) - m_ac(i-1); % kg/s

    % Pipe Section Upstream related
    m_dot_ups_dps(i) = mdot_orifice(P_ups(i-1),P_dps(i-1),polythropic_index,A_m(i),T_u
    m_dot_u_ups(i) = mdot_orifice(P_u(i-1),  P_ups(i-1),polythropic_index,io_A    *10^

    [P_ups(i), T_ups(i), m_ups(i)] = tank_discharge_P_io(P_ups(i-1),T_ups(i-1),m_ups(i
         [T_u(i-1),        T_ups(i-1),          T_ups(i-1)],...
         [m_dot_u_ups(i),  - m_dot_ups_ac(i),   - m_dot_ups_dps(i)] * dt,...
         polythropic_index); % bar, K

    m_dot_ups_net(i) = m_ups(i) - m_ups(i-1); % kg/s

    % Pipe Section Upstream related
    m_dot_dps_d(i) = mdot_orifice(P_dps(i-1),P_d(i-1)  ,polythropic_index,oe_o_A    *1
    m_dot_dps_net(i) = m_dot_ac_dps(i) - m_dot_dps_d(i) + m_dot_ups_dps(i); % kg/s
    m_dps(i) = m_dps(i-1) + m_dot_dps_net(i) * dt; % kg
    [P_dps(i), T_dps(i)] = tank_discharge_P(P_dps(i-1),T_dps(i-1),m_dps(i-1),...
         - m_dot_dps_net(i) * dt,polythropic_index); % bar, K

    [P_dps(i), T_dps(i), m_dps(i)] = tank_discharge_P_io(P_dps(i-1),T_dps(i-1),m_dps(i
         [T_dps(i-1),        T_ac(i-1),         T_ups(i-1)],...
         [-m_dot_dps_d(i), m_dot_ac_dps(i),   m_dot_ups_dps(i)] * dt,...
         polythropic_index); % bar, K

    m_dot_dps_net(i) = m_dps(i) - m_dps(i-1); % kg/s
end
```

Results

```
if false
    figure
    plot(t,m_dot_ups_ac,t,m_dot_ac_dps,t,m_dot_ac_net)
    grid on, grid minor, xlabel('Time [s]'), ylabel('M dot [kg/s]'), title('M dot')
    legend('U to AC', 'AC to D', 'AC net')
    figure
    plot(t,P_u,t,P_ac,t,P_d,t,P_dps,t,P_ups)
    grid on, grid minor, xlabel('Time [s]'), ylabel('Pressure [Bar]'), title('Pressure
    legend('U','AC','D','DPS','UPS')
    figure
    subplot(3,1,1)
```

```
    plot(t,x)
    grid on, grid minor, xlabel('Time [s]'), ylabel('Displacement [m]'), title('Plunge
    subplot(3,1,2)
    plot(t,V_ac)
    grid on, grid minor, xlabel('Time [s]'), ylabel('Volume [mm^3]'), title('Actuation
    subplot(3,1,3)
    plot(t,v)
    grid on, grid minor, xlabel('Time [s]'), ylabel('Velocity [m/s]'), title('Plunger V
    figure
    plot(t,F_ac,t,F_u,t,F_d,t,F)
    grid on, grid minor, xlabel('Time [s]'), ylabel('Force [N]'), title('Forces On Plun
    legend('AC','U','D','Net')
    figure
    plot(t,m_dot_ups_dps,t,m_dot_ac_dps,t,m_dot_dps_d,t,m_dot_dps_net)
    grid on, grid minor, xlabel('Time [s]'), ylabel('M dot [kg/s]'), title('DPS M dot'
    legend('UPS to DPS', 'AC to DPS', 'DPS to D', 'PDS net')
    figure
    plot(t,m_dot_u_ups,t,m_dot_ups_ac,t,m_dot_ups_dps,t,m_dot_ups_net)
    grid on, grid minor, xlabel('Time [s]'), ylabel('M dot [kg/s]'), title('UPS M dot'
    legend('U to UPS', 'UPS to AC', 'UPS to DPS', 'UPS net')
    figure
    plot(t,m_ups,t,m_dps,t,m_ac)
    grid on, grid minor, xlabel('Time [s]'), ylabel('Mass [kg]'), title('Volume masses
    legend('UPS', 'DPS', 'AC')
    figure
    plot(t,P_dps)
    grid on, grid minor, xlabel('Time [s]'), ylabel('Pressure [Bar]'), title('DPS Pres
    figure
    plotyy(t,m_dot_dps_d,t,P_dps),legend('m_dot_dps_d','P_dps')
    figure
    plotyy(t,m_dot_u_ups,t,P_ups),legend('m_dot_dps_d','P_dps'),title('UPS'),legend('m
    figure
    plot(t,T_u,t,T_ac,t,T_d,t,T_dps,t,T_ups)
    grid on, grid minor, xlabel('Time [s]'), ylabel('Temperature [K]'), title('Tempera
    legend('U','AC','D','DPS','UPS')
end
save('micro_hs_v_fill_open_close')
```