ภาคผนวก ก

โปรแกรมสำหรับออกแบบโรงไฟฟ้าวัฏจักรโออาร์ซีเพื่อให้ได้กำลังสุทธิสูงที่สุด

รายละเอียดโปรแกรมเป็นดังต่อไปนี้

```
clc
clear
Params.RP              = py.ctREFPROP.ctREFPROP.REFPROPFunctionLibrary('C:↙
\Program Files (x86)\REFPROP\REFPRP64.DLL');
Params.X3              = 0;
MDOT                   = linspace(2,4,10);
Params.mdot_hf         = 1;
Params.T_hf_in         = 150+273.15;
Params.fluid           = 'R1234ze(E)';
Params.z               = {1 0};
Params.hf_fluid        = 'water';
Params.cf_fluid        = 'water';
Params.T_cf_in         = 30+273.15;
Params.T_cf_out        = 40+273.15;
Params.T_0             = 25+273.15;
Params.P_0             = 101.325e3;
Params.P_water         = 5e6;
for i = 1 : length(MDOT)


     DUMMY    =    refp(Params.fluid,'TQ',Params.T_cf_in,1,'P',Params.RP,↙
Params.z);
     Pcond_xL=    refp(Params.fluid,'TQ',Params.T_cf_in,0,'P',Params.RP,↙
Params.z);
     DUMMY    =    refp(Params.fluid,'TQ',Params.T_cf_in,0,'P',Params.RP,↙
Params.z);
     Pcond_xU=    refp(Params.fluid,'TQ',Params.T_cf_out+10,0,'P',Params.↙
RP,Params.z);
     Pevap_xL=    Pcond_xU;

if i ==1
   TC = refp(Params.fluid,'TQ',Params.T_cf_in,0,'TC',Params.RP,Params.↙
z);
    if TC < Params.T_hf_in
    DUMMY1    =    refp(Params.fluid,'TQ',TC,0 ,'P',Params.RP,Params.z);
    Pevap_xU =    refp(Params.fluid,'TQ',TC-1,Params.X3 ,'P',Params.RP,↙
Params.z);
    else
    DUMMY2    =    refp(Params.fluid,'TQ',Params.T_hf_in,Params.X3 ,'P',↙
Params.RP,Params.z);
    Pevap_xU=   refp(Params.fluid,'TQ',Params.T_hf_in,Params.X3 ,'P',↙
```

```
Params.RP,Params.z);
    end
% elseif T_pp_evap_result(i-1) > 12 || T_pp_evap_result(i-1) < 8
%      i = i -1;
%      Pevap_xU=Pevap_result(i-1)*0.8;
% else
%      Pevap_xU=Pevap_result(i-1)*1.2;
end

mdot_wf       = MDOT(i)
i
over_10_check = 1;
%==== OTP P evap=======
Tol                  = 5e-3;
Num_iter             = 50;
count=0;
ea_old=0;

while (1)
 count=count+1;
 d=(((sqrt(5)-1)/2)*(Pevap_xU-Pevap_xL));
 x1=Pevap_xL+d;
 x2=Pevap_xU-d;

 [Tpp_max1,Pcond_1,Pevap_1,mdot_1,Wnet_orc_1,T_pp_evap_1,T_pp_cond_1]↙
=Function_det_Pcond(Pcond_xL,Pcond_xU,x1,mdot_wf,Params);
 [Tpp_max2,Pcond_2,Pevap_2,mdot_2,Wnet_orc_2,T_pp_evap_2,T_pp_cond_2]↙
=Function_det_Pcond(Pcond_xL,Pcond_xU,x2,mdot_wf,Params);
 f1 = abs(T_pp_evap_1-10);
 f2 = abs(T_pp_evap_2-10);
  if T_pp_cond_1 < 11 && T_pp_cond_1 > 9 && over_10_check == 1
    Pcond_xL= Pcond_1*0.9;
    Pcond_xU= Pcond_1*1.1;
    over_10_check =0;
  end
 if T_pp_cond_2 < 11 && T_pp_cond_2 > 9 && over_10_check == 1
    Pcond_xL= Pcond_2*0.9;
    Pcond_xU= Pcond_2*1.1;
    over_10_check =0;
 end
 ea = abs(x1-x2)/x1;
```

```
    if(ea <= Tol) || count >= Num_iter
        if f1 < f2
        Pcond_result(i)     = Pcond_1;
        Pevap_result(i)     = Pevap_1;
        Mdot_result(i)      = mdot_1;
        Wnet_orc_result(i)  = Wnet_orc_1;
        T_pp_evap_result(i)= T_pp_evap_1;
        T_pp_cond_result(i)= T_pp_cond_1;
        else
        Pcond_result(i)     = Pcond_2;
        Pevap_result(i)     = Pevap_2;
        Mdot_result(i)      = mdot_2;
        Wnet_orc_result(i)  = Wnet_orc_2;
        T_pp_evap_result(i)= T_pp_evap_2;
        T_pp_cond_result(i)= T_pp_cond_2;
        end
        break;
    else
            if   (f1 > f2)
                 Pevap_xU = x1;
            elseif(f1 < f2)
                 Pevap_xL = x2;
            end
            ea_old = ea;
    end
end
%===========================================
end
figure
plot(Mdot_result,Wnet_orc_result)
title('Set A')

[max_W_net,index_max] = max(Wnet_orc_result);
max_mdot=MDOT(index_max)
max_Pcond=Pcond_result(index_max)
max_Pevap=Pevap_result(index_max)

%===plot=====
[RESULT_Tpp_max_result,RESULT_Pcond_result,RESULT_Pevap_result,↙
RESULT_mdot_result,RESULT_Wnet_orc,RESULT_T_pp_evap_result,↙
RESULT_T_pp_cond_result]=ORC_calculation(max_Pcond,max_Pevap,max_mdot,↙
```

```
Params,1);
%=============

function [Tpp_max_result,Pcond_result,Pevap_result,mdot_result,↙
Wnet_orc_result,T_pp_evap_result,T_pp_cond_result]=Function_det_Pcond↙
(Pcond_xL,Pcond_xU,Pevap,mdot_wf,Params)

Tol                  = 5e-3;
Num_iter             = 50;
count=0;
ea_old=0;

while (1)
count=count+1;
d=(((sqrt(5)-1)/2)*(Pcond_xU-Pcond_xL));
x1=Pcond_xL+d;
x2=Pcond_xU-d;
 [Tpp_max1,Pcond_1,Pevap_1,mdot_1,Wnet_orc_1,T_pp_evap_1,T_pp_cond_1]↙
=ORC_calculation(x1,Pevap,mdot_wf,Params,0); %%Not to plot using mode 0
 [Tpp_max2,Pcond_2,Pevap_2,mdot_2,Wnet_orc_2,T_pp_evap_2,T_pp_cond_2]↙
=ORC_calculation(x2,Pevap,mdot_wf,Params,0); %%Not to plot using mode 0
 f1 = abs(T_pp_cond_1-10);
 f2 = abs(T_pp_cond_2-10);
 ea = abs(x1-x2)/x1;
    if(ea <= Tol) || count >= Num_iter
        if f1 < f2
        Tpp_max_result   = f1;
        Pevap_result     = Pevap_1;
        Pcond_result     = Pcond_1;
        mdot_result      = mdot_1;
        Wnet_orc_result  = Wnet_orc_1;
        T_pp_evap_result= T_pp_evap_1;
        T_pp_cond_result= T_pp_cond_1;
        else
        Tpp_max_result   = f2;
        Pevap_result     = Pevap_2;
        Pcond_result     = Pcond_2;
        mdot_result      = mdot_2;
        Wnet_orc_result  = Wnet_orc_2;
        T_pp_evap_result= T_pp_evap_2;
        T_pp_cond_result= T_pp_cond_2;
```

```
        end
        break;
    else
            if(f1 > f2)
                Pcond_xU=x1;
            elseif(f1 < f2)
                Pcond_xL=x2;
            end
            ea_old =ea;
    end
end
end
function [Tpp_max_result,Pcond_result,Pevap_result,mdot_result,Wnet_orc,↙
T_pp_evap,T_pp_cond]=ORC_calculation(Pcond,Pevap,mdot_wf,Params,mode)
RP            = Params.RP;
Wf_ORC        = Params.fluid;
z             = Params.z;

%====Boundary=====
T_hin  = Params.T_hf_in;
Q3     = Params.X3;
T_cin  = Params.T_cf_in-273.15;
T_cout = Params.T_cf_out-273.15;
m_hin  = 1;
p_hin  = 5e6;
eff_p  = .80;
eff_t  = 1;


h_hin  =refp('water','PT',p_hin,T_hin,'h',RP,z);
cp_hin =refp('water','PT',p_hin,T_hin,'cp',RP,z);
cp_win =refp('water','PT',p_hin,273.15+35,'cp',RP,z);
h_cin  =refp('water','PT',p_hin,30+273.15,'h',RP,z);
h_cout =refp('water','PT',p_hin,40+273.15,'h',RP,z);

%====ORC===========
mf_orc     = mdot_wf;
pevap_orc = Pevap;
pcond_orc = Pcond;

Dummy=refp(Wf_ORC,'PQ',pcond_orc,0,'h',RP,z);
```

```
h1_orc=refp(Wf_ORC,'PQ',pcond_orc,0,'h',RP,z);
s1_orc=refp(Wf_ORC,'PQ',pcond_orc,0,'s',RP,z);
T1_orc=refp(Wf_ORC,'PQ',pcond_orc,0,'T',RP,z);

h2s_orc=refp(Wf_ORC,'PS',pevap_orc,s1_orc,'h',RP,z);
h2_orc=h1_orc+(h2s_orc-h1_orc)/eff_p;
s2_orc=refp(Wf_ORC,'PH',pevap_orc,h2_orc,'s',RP,z);
T2_orc=refp(Wf_ORC,'PH',pevap_orc,h2_orc,'T',RP,z);

h3_orc=refp(Wf_ORC,'PQ',pevap_orc,Q3,'h',RP,z);
s3_orc=refp(Wf_ORC,'PQ',pevap_orc,Q3,'s',RP,z);
T3_orc=refp(Wf_ORC,'PH',pevap_orc,h3_orc,'T',RP,z);

h4s_orc=refp(Wf_ORC,'PS',pcond_orc,s3_orc,'h',RP,z);
h4_orc=h3_orc-(h3_orc-h4s_orc)*eff_t;
s4_orc=refp(Wf_ORC,'PH',pcond_orc,h4_orc,'s',RP,z);
T4_orc=refp(Wf_ORC,'PH',pcond_orc,h4_orc,'T',RP,z);

Wnet_orc=mf_orc*((h3_orc-h4_orc)-(h2_orc-h1_orc));
T_hout_orc=T_hin-(mf_orc*(h3_orc-h2_orc))/(cp_hin*m_hin);
%mcf_orc=(mf_orc*(h4_orc-h1_orc))/(10*cp_win);
mcf_orc  =  (mf_orc*(h4_orc-h1_orc))/(h_cout-h_cin);
h_hout_orc=refp('water','PT',p_hin,T_hout_orc,'h',RP,z);


section              = 3;
T23_orc(1)           = T2_orc;
T23_orc(section+1)   = T3_orc;
h23_orc(1)           = h2_orc;
h23_orc(section+1)   = h3_orc;
s23_orc(1)           = s2_orc;
s23_orc(section+1)   = s3_orc;
Thf_orc(1)           = T_hout_orc;
Thf_orc(section+1)   = T_hin;
hhf_orc(1)           = h_hout_orc;
hhf_orc(section+1)   = h_hin;
DeltaTe              = (T_hin-T_hout_orc)/section;

T14_orc(1)           = T1_orc;
T14_orc(section+1)   = T4_orc;
h14_orc(1)           = h1_orc;
```

```
h14_orc(section+1) = h4_orc;
s14_orc(1)         = s1_orc;
s14_orc(section+1) = s4_orc;
Tcf_orc(1)         = 30+273.15;
Tcf_orc(section+1) = 40+273.15;
hcf_orc(1)         = h_cin;
hcf_orc(section+1) = h_cout;
DeltaTc            = (10)/section;
UA_evap            = 0;
UA_cond            = 0;

for i = 2 : section+1
    Thf_orc(i)   = Thf_orc(i-1)+DeltaTe;
    Dummy   = refp('water','PT',p_hin,Thf_orc(i),'H',RP,z);
    hhf_orc(i)   = refp('water','PT',p_hin,Thf_orc(i),'H',RP,z);
    h23_orc(i)   = h23_orc(i-1)  + (m_hin*(hhf_orc(i)-hhf_orc(i-1)))↙
/mf_orc;
    Dummy   = refp(Wf_ORC,'PH',pevap_orc,h23_orc(i),'T',RP,z);
    T23_orc(i)   = refp(Wf_ORC,'PH',pevap_orc,h23_orc(i),'T',RP,z);
    s23_orc(i)   = refp(Wf_ORC,'PH',pevap_orc,h23_orc(i),'S',RP,z);
    T_check_evap(i)   = (Thf_orc(i)-T23_orc(i));

    T_lm_evaps(i-1)       = abs(((Thf_orc(i)-T23_orc(i))-(Thf_orc(i-1)-↙
T23_orc(i-1)))/log((Thf_orc(i)-T23_orc(i))/(Thf_orc(i-1)-T23_orc(i-↙
1))));
    UA_s_evap(i)         = ((h23_orc(i)-h23_orc(i-1))*mf_orc)/T_lm_evaps↙
(i-1);
    UA_evap              = UA_evap + UA_s_evap(i);

   %↙
----------------------------------------------------------------------↙
---------
    Tcf_orc(i)   = Tcf_orc(i-1)+DeltaTc;
    Dummy = refp('water','PT',p_hin,Tcf_orc(i),'H',RP,z);
    hcf_orc(i)   = refp('water','PT',p_hin,Tcf_orc(i),'H',RP,z);
    h14_orc(i)   = h14_orc(i-1)+(mcf_orc*(hcf_orc(i)-hcf_orc(i-1)))↙
/mf_orc;
    Dummy        = refp(Wf_ORC,'PH',pcond_orc,h14_orc(i),'T',RP,z);
    T14_orc(i)   = refp(Wf_ORC,'PH',pcond_orc,h14_orc(i),'T',RP,z);
    s14_orc(i)   = refp(Wf_ORC,'PH',pcond_orc,h14_orc(i),'S',RP,z);
    T_check_cond(i)   = (Tcf_orc(i)-T14_orc(i));
```

```
    T_lm_conds(i-1)        = abs(((Tcf_orc(i)-T14_orc(i))-(Tcf_orc(i-1)-↙
T14_orc(i-1)))/log((Tcf_orc(i)-T14_orc(i))/(Tcf_orc(i-1)-T14_orc(i-↙
1))));
    UA_s_cond(i)           = ((h23_orc(i)-h23_orc(i-1))*mf_orc)/T_lm_conds↙
(i-1);
    UA_cond                = UA_cond + UA_s_cond(i);

end


  Pcond_result     = Pcond;
  Pevap_result     = Pevap;
  mdot_result      = mdot_wf;

  T_check_cond(1)  = T_check_cond(2);
  T_check_evap(1)  = T_check_evap(2);
  if min(T_check_evap) < 0
        T_pp_evap        = 9999;
  else
        T_pp_evap        = min(abs(Thf_orc-T23_orc));
  end

  if max(T_check_cond) >0
        T_pp_cond        = 9999;
  else
        T_pp_cond        = min(abs(Tcf_orc-T14_orc));
  end

  Tpp_max_result   = max(abs(T_pp_cond-10),abs(T_pp_evap-10));


  T_turbine_orc_dot = [T23_orc(section+1) T14_orc(section+1)];
  s_turbine_orc_dot = [s23_orc(section+1) s14_orc(section+1)];
  h_turbine_orc_dot = [h23_orc(section+1) h14_orc(section+1)];
  T_pump_orc_dot    = [T23_orc(1) T14_orc(1)];
  s_pump_orc_dot    = [s23_orc(1) s14_orc(1)];
  h_pump_orc_dot    = [h23_orc(1) h14_orc(1)];

  T_turbine_orc = linspace(T23_orc(section+1),T14_orc(section+1),↙
```

```
section+1);
  s_turbine_orc = linspace(s23_orc(section+1),s14_orc(section+1),↙
section+1);
  h_turbine_orc = linspace(h23_orc(section+1),h14_orc(section+1),↙
section+1);
  T_pump_orc     = linspace(T14_orc(1),T23_orc(1),section+1);
  s_pump_orc     = linspace(s14_orc(1),s23_orc(1),section+1);
  h_pump_orc     = linspace(h14_orc(1),h23_orc(1),section+1);
  reversible_work =mf_orc*(h3_orc-h4s_orc);

 if mode == 1
 figure
 plot(s23_orc,T23_orc,'-k',s23_orc,Thf_orc,'-r',s14_orc,Tcf_orc,'-b',↙
s14_orc,T14_orc,'-k',s_turbine_orc,T_turbine_orc,'-k',s_pump_orc,↙
T_pump_orc,'-k')
 axis([1000 2500 200 500])
 xlabel('Specific Entropy (kJ/kgK)')
 ylabel('Temperature (K)')
 legend('Subcritcal ORC','Heat source','Cooling water')
 title('A')
 end
end
```

ภาคผนวก ข

โปรแกรมสำหรับออกแบบโรงไฟฟ้าวัฏจักรคาลินาแบบ KCS-11 เพื่อให้ได้กำลังสุทธิสูงที่สุด

รายละเอียดโปรแกรมเป็นดังต่อไปนี้

```
clear
clc
global  RP fluid fluid_c
RP = py.ctREFPROP.ctREFPROP.REFPROPFunctionLibrary('C:\Program Files↙
(x86)\REFPROP');
fluid = 'ammonia;water';
fluid_c = 'water';
%-----------Input-----------
mass_faction_a = [0.9];
mass_faction_w = 1-mass_faction_a;
z = {mass_faction_a mass_faction_w}; %First fluid is ammonia Secound is↙
water
Pevap = [6.5]*1e6;
m_wf = 0.4;
i=1;
j=1;
%******Guess T4 (inlet temperature separator)*******
xstop = 99;
K=0;
epsilon = 0.02;
iter= 30;
 a = refp(fluid,'QP',1,Pevap,'T',RP,z);
        b = refp(fluid,'QP',0,Pevap,'T',RP,z);
        while ((xstop>epsilon) && (K<iter))


        phi=(sqrt(5)- 1)/2;
        x1 = a+(1-phi)*(b-a);
        x2 = a+phi*(b-a);
        [Pcond1, Wnet1, Tpp_evap1, Tpp_cond1, LCOE1] = Golden_Pcond↙
(m_wf, Pevap, z, x1, mass_faction_a);
        [Pcond2, Wnet2, Tpp_evap2, Tpp_cond2, LCOE2] = Golden_Pcond↙
(m_wf, Pevap, z, x2, mass_faction_a);


            if(Tpp_evap1<Tpp_evap2)
                b=x2;
                x2=x1;
                x1=a+(1-phi)*(b-a);
            else
                a=x1;
```

```
                x1=x2;
                x2=a+phi*(b-a);
            end

            K=K+1
            xstop = 100*abs(x1-x2)/x2
        end

        if (Tpp_cond1<Tpp_cond2)
            Pevap/1e6
            P1(i,j) = Pcond1/1e6
            T4(i,j) = x1
            Wnet(i,j) = Wnet1
            Tpp_evap(i,j) = Tpp_evap1
            Tpp_cond(i,j) = Tpp_cond1
            LCOE(i,j) = LCOE1;

        else
            Pevap/1e6
            P1(i,j) = Pcond2/1e6
            T4(i,j) = x2
            Wnet(i,j) = Wnet2
            Tpp_evap(i,j) = Tpp_evap2
            Tpp_cond(i,j) = Tpp_cond2
            LCOE(i,j) = LCOE2;

        end

%===========Function======================
function [P1, Wnet, Tpp_evap, Tpp_cond, LCOE] = Golden_Pcond(m_wf, P2,↙
z, T4, z_f1)
    global  RP fluid
    a = refp(fluid,'QT',0,273.15 + 30 + 5,'P',RP,z);↙
% start of interval condensation pressure
    b = refp(fluid,'QT',0,273.15 + 40 + 10,'P',RP,z);↙
% end of interval condensation pressure
    epsilon = 0.02;                % accuracy value
    iter= 30;                        % maximum number of iterations
    phi=(sqrt(5)- 1)/2;        % golden proportion coefficient, around↙
0.618
    x1 = a+(1-phi)*(b-a);              % computing x values
```

```
    x2 = a+phi*(b-a);
    [Tpp_evap1, Tpp_cond1, Wnet1, LCOE1] = KCS11(m_wf, x1, P2, z, T4,↙
z_f1);
    [Tpp_evap2, Tpp_cond2, Wnet2, LCOE2] = KCS11(m_wf, x2, P2, z, T4,↙
z_f1);
    H = 1;
    xstop = 100*abs(x1-x2)/x2;

    while ((xstop>epsilon) && (H<iter))

        if(Tpp_cond1<Tpp_cond2)
            b=x2;
            x2=x1;
            x1=a+(1-phi)*(b-a);
            [Tpp_evap1, Tpp_cond1, Wnet1, LCOE1] = KCS11(m_wf, x1, P2,↙
z, T4, z_f1);
            [Tpp_evap2, Tpp_cond2, Wnet2, LCOE2] = KCS11(m_wf, x2, P2,↙
z, T4, z_f1);
        else
            a=x1;
            x1=x2;
            x2=a+phi*(b-a);
            [Tpp_evap1, Tpp_cond1, Wnet1, LCOE1] = KCS11(m_wf, x1, P2,↙
z, T4, z_f1);
            [Tpp_evap2, Tpp_cond2, Wnet2, LCOE2] = KCS11(m_wf, x2, P2,↙
z, T4, z_f1);
        end

        H=H+1;
        xstop = 100*abs(x1-x2)/x2;
    end
    number_iteration_Pcond = H;
    if (Tpp_cond1<Tpp_cond2)
        P1 = x1;
        Wnet = Wnet1;
        Tpp_evap = Tpp_evap1;
        Tpp_cond = Tpp_cond1;
        LCOE = LCOE1;

    else
        P1 = x2;
```

```
        Wnet = Wnet2;
        Tpp_evap = Tpp_evap2;
        Tpp_cond = Tpp_cond2;
        LCOE = LCOE2;

    end
end
function [Tpp_evap, Tpp_cond, Wnet, LCOE] = KCS11(m_wf, P1, P2, z, T4,↙
z_f1)
%↙
-----------------------------------------------------------------------↙
--Input↙
parameter--------------------------------------------------------------↙
-----------%
global  RP fluid fluid_c

z_c = {1 0 };

Phf = 10e6;
eff_gen = 1;
m_hot = 1;
Pcf = 1e5;
Tcold_in = 273.15 + 30;
Tcold_out = 273.15 + 40;
Thot_in = 273.15 + 200; %Ths
P_0 = 1e5;
T0 = 273.15+25;
isen_p = 0.75;
isen_t = 0.8;
n_evap = 20;
n_cond = 20;
n_HT = 10;
PPTD_cond = 10;
PPTD_evap = 10;
Eff_HX = 0.8;
%

%State 1: Pump inlet
T11 = refp(fluid,'QP',0,P1,'T',RP,z);
T1 = refp(fluid,'PQmass',P1,0,'T',RP,z);
h1 = refp(fluid,'PQmass',P1,0,'h',RP,z);
```

```
s1 = refp(fluid,'PQmass',P1,0,'s',RP,z);

Tcri = refp(fluid,'PQmass',P1,0,'Tc',RP,z) - 273.15;

%State 2: HT rec inlet (cold fluid)
s2s = s1;
h2s = refp(fluid,'PS',P2,s2s,'h',RP,z);
h2 = h1 + (h2s - h1)/isen_p;
T2 = refp(fluid,'hP',h2,P2,'T',RP,z);
if T2<T1
    T2 = T1;
end

%State 4: Separator inlet
h4 = refp(fluid,'PT',P2,T4,'h',RP,z);

%State 5: Turbine inlet
% % for 2 fluid
[m_f_f1_V]  = refp(fluid,'PT',P2,T4,'xmassvap',RP,z);%% xmassvap = find↙
mass friction for vapor phase
m_f_f2_V=1-m_f_f1_V;
z5 = {m_f_f1_V m_f_f2_V};

%State 7: HT rec inlet (hot fluid)
% for 2 fluid
[m_f_f1_L]  = refp(fluid,'PT',P2,T4,'xmassliq',RP,z);  %% xmassliq =↙
find mass friction for liquid phase
m_f_f2_L=1-m_f_f1_L;
z7 = {m_f_f1_L m_f_f2_L};z7 = {m_f_f1_L m_f_f2_L};
m5 = m_wf*(z_f1 - m_f_f1_L)/(m_f_f1_V - m_f_f1_L );
m7 =  m_wf - m5;
h5 = refp(fluid,'PT',P2,T4,'h',RP,z5);
s5 = refp(fluid,'PT',P2,T4,'s',RP,z5);

%State 6: Mixer inlet (rich ammonia)
s6s = s5;
h6s = refp(fluid,'PS',P1,s6s,'h',RP,z5);
h6 = h5 - isen_t*(h5 - h6s);
h7 = refp(fluid,'PT',P2,T4,'h',RP,z7);

%State 8: Expansion valve inlet
```

```
T7 = T4;
T8 = T7 - Eff_HX*(T7 - T2);
h8 = refp(fluid,'PT',P2,T8,'h',RP,z7);
Q_HT = m7*(h7 - h8);

%State 3: Evaporator inlet
h3 = h2 + Q_HT/m_wf;
T3 = refp(fluid,'PH',P2,h3,'T',RP,z);

%State 9: Mixer inlet (lean ammonia)
h9 = h8;

%State 10: Condenser inlet
h10 = (m5*h6 + m7*h9)/m_wf;
T10 = refp(fluid,'Ph',P1,h10,'T',RP,z);

%↙
-------------------------------------------------------------------------↙
--Thermodynamic↙
analysis----------------------------------------------------------------↙
----------%
Wturbine = m5*(h5 - h6)/1000;
Wpump = m_wf*(h2 - h1)/1000;
Wgen = Wturbine*eff_gen;
Wnet = Wturbine - Wpump;
Qin = m_wf*(h4 - h3)/1000;
        h_hot_in_dummy = refp(fluid_c,'TP',Thot_in,Phf,'h',RP,z_c);
        h_hot_in = refp(fluid_c,'TP',Thot_in,Phf,'h',RP,z_c);
        s_hot_in = refp(fluid_c,'TP',Thot_in,Phf,'s',RP,z_c);
        h_hot_out = h_hot_in - (1000*Qin/m_hot);
        s_hot_out = refp(fluid_c,'HP',h_hot_out,Phf,'s',RP,z_c);
        h0_hf = refp(fluid_c,'TP',T0,P_0,'h',RP,z_c);
        s0_hf = refp(fluid_c,'TP',T0,P_0,'s',RP,z_c);
        cp_hot = refp(fluid_c,'PT',Phf,Thot_in,'cp',RP,z_c);
        Thot_out = Thot_in - (1000*Qin/(m_hot*cp_hot));
        T_hot_avg = (Thot_in + Thot_out)/2;
        Thotout = Thot_out - 273.15;
Qout = m_wf*(h10 - h1)/1000;
        h_cold_in = refp(fluid_c,'TP',Tcold_in,Pcf,'h',RP,z_c);
        h_cold_out = refp(fluid_c,'TP',Tcold_out,Pcf,'h',RP,z_c);
        s_cold_in = refp(fluid_c,'TP',Tcold_in,Pcf,'s',RP,z_c);
```

```
        s_cold_out = refp(fluid_c,'TP',Tcold_out,Pcf,'s',RP,z_c);
        m_cold = 1000*Qout/(h_cold_out - h_cold_in);
        T_cold_avg = (Tcold_in + Tcold_out)/2;
% Eff1 = 100*Wnet/Qin
% Qin
% Qout
% Wnet

%↙
------------------------------------------------------------------------↙
--↙
Discretization---------------------------------------------------------↙
----------------%
    %Evaporator
         [Tpp_e T_hf h_hf T_wf_e h_wf_e Photf Pwf_e UA_E] =↙
Discretization_Evap(n_evap, h_hot_out, h_hot_in, Thot_out, Thot_in,↙
fluid_c, z_c, Phf, Phf, h3, h4, T3, T4, fluid, z, P2, P2, m_hot, RP);
         Tpp_evap = abs(Tpp_e - PPTD_evap);

    %Condenser
         [Tpp_c T_wf_c h_wf_c T_cf h_cf Pwf_c Pcoldf UA_C] =↙
Discretization_Cond(n_cond, h1, h10, T1, T10,  fluid, z, P1, P1,↙
h_cold_in, h_cold_out, Tcold_in, Tcold_out, fluid_c, z_c, Pcf, Pcf,↙
m_wf, RP);
         Tpp_cond = abs(Tpp_c - PPTD_cond);
    %HT rec
        [Tpp_HT_rec T_87 h_87 T_23 h_23 P87 P23 UA_H] =↙
Discretization_ex(n_HT, h8, h7, T8, T7,  fluid, z7, P2, P2, h2, h3, T2,↙
T3, fluid, z, P2, P2, m_wf, RP);

Eff1 = 100*Wnet/Qin;
% LCOE = 1;
%↙
------------------------------------------------------------------------↙
--------↙
LCOE-------------------------------------------------------------------↙
------------%
U_evap = 39.7;
U_cond = 709.3;
U_HT_rec = 638.4;
C_hx = 588;
```

```
C_tur0 = 4405;
C_pump0 = 1120;
crf = 0.87;
Wgen_kW = Wgen;
Wturbine_kW = Wturbine;
N_year = 40;
i_c = 0.0675;
CRF = (i_c*(i_c+1)^N_year)/((i_c+1)^N_year - 1);
hr_net = 365*24*crf;
Ele_year = Wnet*hr_net;
A_evap = UA_E/U_evap;
A_cond = UA_C/U_cond;
A_rec = UA_H/U_HT_rec;

C_evap = C_hx*(A_evap)^0.8;
C_cond = C_hx*(A_cond)^0.8;
C_rec = C_hx*(A_rec)^0.8;
C_tur =  C_tur0*(Wturbine_kW)^0.7;
C_pump = C_pump0*(Wpump)^0.8;
C_gen = 10*10^6*(Wgen_kW/(160*10^3))^0.7;
C_sep = 1; %minimum value, it is a estimate
C_pec = C_tur + C_gen + C_cond + C_pump + C_sep + C_rec + C_evap;
C_pip = 0.66*C_pec;
C_insc = 0.1*C_pec;
C_el = 0.1*C_pec;
C_inst = 0.45*C_pec;
C_misc = C_pip + C_insc + C_el + C_inst;
C_inv = C_pec + C_misc;
C_OaM = 5*hr_net;
LCOE = (CRF*C_inv + C_OaM)/Ele_year;
end
function [Tpp Th hh Tc hc Pc Ph sum_UA] = Discretization_Cond(n, h_hf_L,↙
h_hf_R, T_hf_L, T_hf_R,  fluid_hf, z_hf, Phf_L, Phf_R, h_cf_L, h_cf_R,↙
T_cf_L, T_cf_R, fluid_cf, z_cf, Pcf_L,Pcf_R, m_hot, RP)
%hf = hot fluid, cf = cold fluid
Tcri = refp(fluid_hf,'QP',1,0,'Tc',RP,z_hf) - 273.15;
sum_UA  = 0;
h_hot(1) = h_hf_L;
h_hot(n + 1) = h_hf_R;
del_h_hot = abs(h_hf_L - h_hf_R)/(n);
T_hot(1) = T_hf_L;
```

```
T_hot(n+ 1) = T_hf_R;
del_T_hot = abs(T_hf_L - T_hf_R)/(n);
del_T_cold = abs(T_cf_L - T_cf_R)/(n);
Phf(1) = Phf_L;
Phf(n+ 1) = Phf_R;
del_Phf = abs(Phf(1) - Phf(n+1))/(n);
h_cold(1)  = h_cf_L;
h_cold(n+ 1) = h_cf_R;
del_h_cold = abs(h_cf_L - h_cf_R)/(n);
T_cold(1) = T_cf_L;
T_cold(n+ 1) = T_cf_R;
Pcf(1) = Pcf_L;
Pcf(n+ 1) = Pcf_R;
del_Pcf = abs(Pcf(1) - Pcf(n+1))/(n);
diffTemp(1) = abs(T_hot(1) - T_cold(1));
diffTemp(n + 1) = abs(T_hot(n+ 1) - T_cold(n+ 1));
for i = 2: n +1
    %hot fluid
    Phf(i) = Phf(i - 1) + del_Phf;
    h_hot(i) = h_hot(i - 1) + del_h_hot;
    T_hot_dummy = refp(fluid_hf,'Ph',Phf(i),h_hot(i),'T',RP,z_hf);
    T_hot1 = refp(fluid_hf,'Ph',Phf(i),h_hot(i),'T',RP,z_hf);
    T_hot(i) = refp(fluid_hf,'Ph',Phf(i),h_hot(i),'T',RP,z_hf);
    if T_hot(i) < 200
             T_hot(i) = T_hot(i-1);
    end

    h_cold(i) = h_cold(i - 1) + del_h_cold;
    Pcf(i) = Pcf(i - 1) - del_Pcf;
    T_cold(i) = T_cold(i-1) + del_T_cold;

    diffTemp(i) = abs(T_hot(i) - T_cold(i));
end

%UA heat exchanger
 for i = 1: n
     dT_L(i) = (T_hot(i) - T_cold(i));
     dT_R(i) = (T_hot(i+1) - T_cold(i+1));
     LMTD(i) = (dT_L(i) - dT_R(i))/log(dT_L(i)/dT_R(i));
     UA(i) = m_hot*(h_hot(i+1) - h_hot(i))/LMTD(i);
 end
```

```
 sum_UA = sum(UA);
Tpp = min(diffTemp);
Th = T_hot;
hh = h_hot;
Tc = T_cold;
hc = h_cold;
Pc = Pcf;
Ph = Phf;
end
function [Tpp Th hh Tc hc Pc Ph sum_UA Q] = Discretization_Evap(n,↙
h_hf_L, h_hf_R, T_hf_L, T_hf_R,  fluid_hf, z_hf, Phf_L, Phf_R, h_cf_L,↙
h_cf_R, T_cf_L, T_cf_R, fluid_cf, z_cf, Pcf_L,Pcf_R, m_hot, RP)
%hf = hot fluid, cf = cold fluid
Tcri = refp(fluid_hf,'QP',1,0,'Tc',RP,z_hf) - 273.15;
sum_UA  = 0;
h_hot(1) = h_hf_L;
h_hot(n + 1) = h_hf_R;
del_h_hot = abs(h_hf_L - h_hf_R)/(n);
T_hot(1) = T_hf_L;
T_hot(n+ 1) = T_hf_R;
del_T_hot = abs(T_hf_L - T_hf_R)/(n);
del_T_cold = abs(T_cf_L - T_cf_R)/(n);
Phf(1) = Phf_L;
Phf(n+ 1) = Phf_R;
del_Phf = abs(Phf(1) - Phf(n+1))/(n);
h_cold(1)  = h_cf_L;
h_cold(n+ 1) = h_cf_R;
del_h_cold = abs(h_cf_L - h_cf_R)/(n);
T_cold(1) = T_cf_L;
T_cold(n+ 1) = T_cf_R;
Pcf(1) = Pcf_L;
Pcf(n+ 1) = Pcf_R;
del_Pcf = abs(Pcf(1) - Pcf(n+1))/(n);
diffTemp(1) = abs(T_hot(1) - T_cold(1));
diffTemp(n + 1) = abs(T_hot(n+ 1) - T_cold(n));
for i = 2: n +1
    %hot fluid
    Phf(i) = Phf(i - 1) + del_Phf;
    h_hot(i) = h_hot(i - 1) + del_h_hot;
    T_hot(i) = T_hot(i-1) + del_T_hot;
```

```
    h_cold(i) = h_cold(i - 1) + del_h_cold;
    Pcf(i) = Pcf(i - 1) - del_Pcf;
    T_cold_dummy = refp(fluid_cf,'Ph',Pcf(i),h_cold(i),'T',RP,z_cf);
    T_cold(i) = refp(fluid_cf,'Ph',Pcf(i),h_cold(i),'T',RP,z_cf);
    if T_cold(i) < T_cold(i - 1)
        del_T_cold = abs(T_cf_R - T_cold(i-1))/(n - i + 2);
        T_cold(i) = T_cold(i-1) + del_T_cold ;
    end
    diffTemp(i) = abs(T_hot(i) - T_cold(i));
end

%UA heat exchanger
 for i = 1: n
     dT_L(i) = (T_hot(i) - T_cold(i));
     dT_R(i) = (T_hot(i+1) - T_cold(i+1));
     LMTD(i) = (dT_L(i) - dT_R(i))/log(dT_L(i)/dT_R(i));
     UA(i) = m_hot*(h_hot(i+1) - h_hot(i))/LMTD(i);
     Q(i) = m_hot*(h_hot(i+1) - h_hot(i));
 end
 sum_UA = sum(UA);
Tpp = min(diffTemp);
Th = T_hot;
hh = h_hot;
Tc = T_cold;
hc = h_cold;
Pc = Pcf;
Ph = Phf;
end
function [Tpp Th hh Tc hc Pc Ph sum_UA] = Discretization_ex(n, h_hf_L,↙
h_hf_R, T_hf_L, T_hf_R,  fluid_hf, z_hf, Phf_L, Phf_R, h_cf_L, h_cf_R,↙
T_cf_L, T_cf_R, fluid_cf, z_cf, Pcf_L,Pcf_R, m_hot, RP)
%hf = hot fluid, cf = cold fluid
Tcri = refp(fluid_hf,'QP',1,0,'Tc',RP,z_hf) - 273.15;
sum_UA  = 0;
h_hot(1) = h_hf_L;
h_hot(n + 1) = h_hf_R;
del_h_hot = abs(h_hf_L - h_hf_R)/(n);
T_hot(1) = T_hf_L;
T_hot(n+ 1) = T_hf_R;
del_T_hot = abs(T_hf_L - T_hf_R)/(n);
del_T_cold = abs(T_cf_L - T_cf_R)/(n);
```

```
Phf(1) = Phf_L;
Phf(n+ 1) = Phf_R;
del_Phf = abs(Phf(1) - Phf(n+1))/(n);
h_cold(1)  = h_cf_L;
h_cold(n+ 1) = h_cf_R;
del_h_cold = abs(h_cf_L - h_cf_R)/(n);
T_cold(1) = T_cf_L;
T_cold(n+ 1) = T_cf_R;
Pcf(1) = Pcf_L;
Pcf(n+ 1) = Pcf_R;
del_Pcf = abs(Pcf(1) - Pcf(n+1))/(n);
diffTemp(1) = abs(T_hot(1) - T_cold(1));
diffTemp(n + 1) = abs(T_hot(n+ 1) - T_cold(n+ 1));
for i = 2: n +1
    %hot fluid
    Phf(i) = Phf(i - 1) + del_Phf;
    h_hot(i) = h_hot(i - 1) + del_h_hot;
    T_hot_dummy = refp(fluid_hf,'Ph',Phf(i),h_hot(i),'T',RP,z_hf);
    T_hot(i) = refp(fluid_hf,'Ph',Phf(i),h_hot(i),'T',RP,z_hf);
    if T_hot(i) < T_hot(i - 1)
             T_hot(i) = T_hot(i-1) + del_T_hot;
    else (abs(T_hot(i) - T_hot(i - 1)) < 0.5 );
            T_hot(i) = T_hot(i-1) + del_T_hot;
    end

    h_cold(i) = h_cold(i - 1) + del_h_cold;
    Pcf(i) = Pcf(i - 1) - del_Pcf;
    T_cold_dummy = refp(fluid_cf,'Ph',Pcf(i),h_cold(i),'T',RP,z_cf);
    T_cold(i) = refp(fluid_cf,'Ph',Pcf(i),h_cold(i),'T',RP,z_cf);
    if T_cold(i) < T_cold(i - 1)
        del_T_cold = abs(T_cf_R - T_cold(i-1))/(n - i + 2);
        T_cold(i) = T_cold(i-1) + del_T_cold ;
    end
    diffTemp(i) = abs(T_hot(i) - T_cold(i));
end

%UA heat exchanger
 for i = 1: n
     dT_L(i) = (T_hot(i) - T_cold(i));
     dT_R(i) = (T_hot(i+1) - T_cold(i+1));
     LMTD(i) = (dT_L(i) - dT_R(i))/log(dT_L(i)/dT_R(i));
```

ภาคผนวก ค

โปรแกรมสำหรับออกแบบเทสลาเทอร์ไบน์เพื่อให้กำลังสูงที่สุด

รายละเอียดโปรแกรมเป็นดังต่อไปนี้

```
clc
clear
RP = py.ctREFPROP.ctREFPROP.REFPROPFunctionLibrary('C:\Program Files↙
(x86)\REFPROP\REFPRP64.DLL');
z = {1  0};

P3_Array = [0.455536    0.455536    0.455536    0.455536    0.442376];
P1_Array = [1.855810    1.278437    1.087585    1.064399    1.067544];
M_Array  = [3.06    2.94    1.94    1.33    1.00];
X_Array  = [0 0.25 0.5 0.75 1];
RPM_Array= [3000 3200 3400 3600 3800 4000];
for i = 1 : 1
for k = 4: length(RPM_Array)

seclect  = i;
k

fluid_Array = 'R236ea'

RPM = RPM_Array(k)
%%ORC condition
P1 = P1_Array(seclect)*1e6;
P3 = P3_Array(seclect)*1e6;
Mdot = M_Array(seclect);
fluid=fluid_Array;
%%%geometry
N_disk = 50;
D02 = 400e-3;
%D03 = 80e-3;
X1 = X_Array(seclect);
v1 = 0;

%%STAGE I
%liner search PR
PR_xU = 0.9;
PR_xL = 0.65;
Tol                 = 5e-3;
Num_iter            = 200;
count=0;
ea_old=0;
```

```
while (1)
count=count+1;
d=(((sqrt(5)-1)/2)*(PR_xU-PR_xL));
x1=PR_xL+d
x2=PR_xU-d;
 [W_turbine_11,BD_11]=Function_Det_DB(fluid,x1,N_disk,D02,P1,P3,Mdot,X1,↙
v1,RPM,RP,z);
 [W_turbine_12,BD_12]=Function_Det_DB(fluid,x2,N_disk,D02,P1,P3,Mdot,X1,↙
v1,RPM,RP,z);
 f1 = -W_turbine_11;
 f2 = -W_turbine_12;
 ea = abs(x1-x2)/x1;
 FF_CHECK = abs(ea_old-ea)/ea;
    if(ea <= Tol) || count >= Num_iter || FF_CHECK == 0
        [W_turbine_1(i,k),Eta_tos_turbine_1(i,k),X_des_tur_1(i,k),↙
Eta_II_turbine_1(i,k),v3_1(i,k),X3_1(i,k),h3_1(i,k),D3_1,rpm1,Aera(i,k),↙
W_DL(i,k),X_DL(i,k),expansion(i,k),v2(i,k)]↙
=OMFS_Tesla_Function_VR3_GiveRPM__Ref_Newnozzle_v3(fluid,x1,BD_11,↙
N_disk,D02,P1,P3,Mdot,X1,v1,RPM,RP,z)
        PR(i,k)  = x1
        BD(i,k)  = BD_11
        RPM_recheck(i,k)= rpm1
        D03(i,k)  = D3_1
        break;
    else
            if(f1 > f2)
                PR_xU=x1;
            elseif(f1 < f2)
                PR_xL=x2;
            end
             ea_old=ea;
    end
    end

end
end
function [W_turbine,x1]=Function_Det_DB(fluid,PR,N_disk,D02,P2,P3,Mdot,↙
X3,v3,RPM,RP,z)
Tol                  = 5e-3;
Num_iter             = 200;
count=0;
```

```
BD_xU = 25e-4;
BD_xL = 10e-4;

while (1)
 count=count+1;
 d=(((sqrt(5)-1)/2)*(BD_xU-BD_xL));
 x1=BD_xL+d;
 x2=BD_xU-d;

 f1=-OMFS_Tesla_Function_VR3_GiveRPM__Ref_Newnozzle_v3(fluid,PR,x1,↙
N_disk,D02,P2,P3,Mdot,X3,v3,RPM,RP,z);
 f2=-OMFS_Tesla_Function_VR3_GiveRPM__Ref_Newnozzle_v3(fluid,PR,x2,↙
N_disk,D02,P2,P3,Mdot,X3,v3,RPM,RP,z);
 ea = abs(x1-x2)/x1;
    if(ea <= Tol) || count >= Num_iter
        W_turbine=-f1;
        break;
    else
            if(f1 > f2)
                 BD_xU = x1;
            elseif(f1 < f2)
                 BD_xL = x2;
            end
                 ea_old = ea;
    end
end
end

function [W_turbine,Eta_tos_turbine,X_des_tur,Eta_II_turbine,v3,X3,h3,↙
D3,rpm,Aera,W_DL,X_DL,expansion,v2]↙
=OMFS_Tesla_Function_VR3_GiveRPM__Ref_Newnozzle_v3(fluid,pressure_ratio,↙
BD,N_disk,D02,P1,P3,Mdot,X1,v1,RPM,RP,z)
%new viscosity model + Two phase

mdot        = Mdot/N_disk;
T1          = refp(fluid,'PQ',P1 ,X1   ,'T',RP,z);%c
h1          = refp(fluid,'PQ',P1 ,X1   ,'H',RP,z);
s1          = refp(fluid,'PQ',P1 ,X1   ,'s',RP,z);
h01         = refp(fluid,'PQ',P1 ,X1   ,'h',RP,z)+0.5*v1^2;
rho1        = refp(fluid,'PQ',P1 ,X1   ,'d',RP,z);
```

```
h1fg        = refp(fluid,'PQ',P1,1,'h',RP,z)-refp(fluid,'PQ',P1,0,'h',↙
RP,z);
h1f         = refp(fluid,'PQ',P1,0,'h',RP,z);
X1s         = (h1-h1f)/h1fg;
mu1_g_1     = refp(fluid,'PQ',P1,1,'vis',RP,z);
mu1_g_0     = refp(fluid,'PQ',P1,0,'vis',RP,z);
mu1         = mu1_g_1*X1s+(1-X1s)*mu1_g_0;


P2          = P1-(P1-P3)*pressure_ratio;
R02R03      = 0.0005;
h01         = h1+0.5*v1^2;
s2s         = s1;
h02s        = h01;
h2s         = refp(fluid,'PS',P2 ,s2s ,'h',RP,z);
v2          = 0.9*sqrt(2*(h02s-h2s));

h2          = h01-0.5*v2^2;
h02         = h01-sqrt(2*(h02s-h2s));
s2          = refp(fluid,'Ph',P2,h2,'s',RP,z);
T2          = refp(fluid,'PH',P2 ,h2 ,'T',RP,z);

h2fg         = refp(fluid,'PQ',P2,1,'h',RP,z)-refp(fluid,'PQ',P2,0,'h',↙
RP,z);
h2f          = refp(fluid,'PQ',P2,0,'h',RP,z);
X2s         = (h2-h2f)/h2fg;

if X2s < 1
mu2_g_1      = refp(fluid,'PQ',P2,1,'vis',RP,z);
mu2_g_0      = refp(fluid,'PQ',P2,0,'vis',RP,z);
mu2         = mu2_g_1*X2s+(1-X2s)*mu2_g_0;
rho2        = refp(fluid,'Ph',P2,h2,'d',RP,z);
else
mu2      = refp(fluid,'PT',P2,T2,'vis',RP,z);
rho2     = refp(fluid,'PT',P2,T2,'d',RP,z);
end

%=========Rotor calculation=================
aplpla2  = 87.5;
mc       = mdot;
T(1)     = T2;
```

```
p(1)      = P2;
b         = D02*BD;
R02       = D02/2;
R03       = R02*R02R03;

mu(1)     = mu2;
pho(1)    = rho2;
X(1)      = X2s;
r         = linspace(R02,R03,1000);
vr(1)     = mc/(2*pi*r(1)*b*pho(1)); %Radial velocity, v_r (m/s)
vt(1)     = v2*sind(aplpla2);
vt(1)     = (v2^2-vr(1)^2)^.5;


omega_otp  = 0.9*vt(1)/R02;
rpm_otp    = omega_otp*60/(2*pi)
rpm       = RPM;
omega     = 2*pi*RPM/60;

ut(1)   = omega*r(1);
wt(1)  = vt(1)-ut(1);
v(1)   = sqrt(vt(1).^2+vr(1).^2);
w(1)   = sqrt(wt(1).^2+vr(1).^2);
h(1)        = h2;
h0(1)       = h02;
%Rothalpy method 1
I2          = h02-ut(1)*vt(1); %Rothalpy constant
%Rothalpy method 2
p0(1)       = p(1)/pho(1);
delr        = r(2)-r(1);
del_h_isen = 0;
R(1)        = r(1);
for i = 2 : length(r)
 %two phase check
 R(i)     = r(i);
 %Churchill correlation
 Dh = 2*b;
  Re= (mc/(pi*r(i)*mu(i-1))); %Manfrida
 AA = ((7/Re)^0.9);
 AB = 0.27*((0.05*10^-3)/Dh); %stainless (0.050mm)
 A  = (2.457*log(1/((AA+AB))))^16;
```

```
 B   = (37530/Re)^16;
 f_TP= 2*(((8/Re)^12)+(1/((A+B)^1.5)))^(1/12);
 R(i)     = r(i);
 %Radial velocity, v_r (m/s)
 vr(i)   = mc/(2*pi*r(i)*b*pho(i-1));
 %Tangental velocity, v_t (m/s)
 ut(i)    = omega*r(i);
 dvt_A    = -2*(f_TP/Dh)*((vt(i-1)-(ut(i-1)))/(-vr(i-1)));%need to change↙
the direction of vr
 dvt_B_A = (vt(i-1)-(ut(i-1)))^2;
 dvt_B_B = (-vr(i-1))^2;%need to change the direction of vr
 dvt_B    = sqrt(dvt_B_A+dvt_B_B);
 dvt_C    = vt(i-1)/r(i-1);
 dvt      = dvt_A*dvt_B-dvt_C;
 vt(i)    = delr*dvt+vt(i-1);
 wt(i)    = vt(i)-ut(i);
 v(i)     = sqrt(vt(i).^2+vr(i).^2);
 w(i)     = sqrt(wt(i).^2+vr(i).^2);
 %Static pressure, p (Pa)
 dp_A      = (pho(i-1)*vt(i-1)^2)/(r(i-1));
 dp_B      = (pho(i-1)*vr(i-1)^2)/(r(i-1));
 dp_C      = (2*pho(i-1)*f_TP/Dh)*dvt_B*(vr(i));%need to change the↙
direction of vr
 dp        = dp_A+dp_B+dp_C;

 %==Properties calculation===
 p(i)    = dp*delr+p(i-1);

 %Static enthalpy, h (kJ/kg)
 h0(i)   = I2+ut(i)*vt(i);
 h(i)    = h0(i)-0.5*v(i)^2;
 %Static Temperature, T (K)s
 T(i)    = refp(fluid,'Ph',p(i),h(i),'t',RP,z);
 %T0(i)   = refp(fluid,'Ph',p0(i),h0(i),'t',RP,z);

 hfg          = refp(fluid,'PQ',p(i),1,'h',RP,z)-refp(fluid,'PQ',p(i),↙
0,'h',RP,z);
 hf           = refp(fluid,'PQ',p(i),0,'h',RP,z);
 X(i)         = (h(i)-hf)/hfg;
if X(i) <= 1
```

```
mu_g_0       = refp(fluid,'PQ',p(i),0,'vis',RP,z);
mu(i)        = mu_g_1*X(i)+(1-X(i))*mu_g_0;
pho(i)       = refp(fluid,'PQ',p(i), X(i),'d',RP,z);
else
mu(i)       = refp(fluid,'PT',p(i),T(i),'vis',RP,z);
pho(i)      = refp(fluid,'PT',p(i),T(i),'d',RP,z);
end

v3      = v(i);
 D3      = r(i)*2;
 if  p(i) <= P3

    break
end
end
hfg     = refp(fluid,'PQ',p(i),1,'h',RP,z)-refp(fluid,'PQ',p(i),0,'h',RP,↙
z);
hf      = refp(fluid,'PQ',p(i),0,'h',RP,z);
X3       = (h(i)-hf)/hfg;

%velocity calulation
wt_b_U0    = wt./ut(1);
alpha_in   = atand(vt(1)/vr(1));
alpha_out  = atand(vt(i)/vr(i));
beta_in    = atand(wt(1)/vr(1));
beta_out   = atand(wt(i)/vr(i));

h3                = h(i);
h03               = h0(i);
h3ss              = refp(fluid,'PS',p(i),s1,'h',RP,z);
h03ss             = h3ss+0.5*v(i)^2;
W_turbine         = N_disk*mc*(vt(1)*ut(1)-vt(i)*ut(i));
W_turbine_H       = N_disk*mc*(h02-h03);
W_isen            = N_disk*mc*(h01-h3ss);
Eta_tos_turbine =  (vt(1)*ut(1)-vt(i)*ut(i))/(h01-h3ss);
Eta_tot_turbine =  (vt(1)*ut(1)-vt(i)*ut(i))/(h01-h03ss);
P3_out            = p(i);
R03_out           = r(i);
Aera              = 2*(N_disk-1)*((pi*R02^2)-(pi*r(i)^2));%Exergy↙
destruction
T_surr            = 25+275.15;
```

```
P_surr           = 101.325e3;
s3               = refp(fluid,'PH',p(i),h03,'s',RP,z);
s_surr           = PropsSI('S', 'T', T_surr, 'P', P_surr ,fluid);
h_surr           = PropsSI('H', 'T', T_surr, 'P', P_surr ,fluid);
x01              = (h1-h_surr)-T_surr*(s1-s_surr)+0.5*v1^2;
x03              = (h3-h_surr)-T_surr*(s3-s_surr)+0.5*v(i)^2;
X_des_tur        = N_disk*mc*(x01-x03)-W_turbine;
Eta_II_turbine   = W_turbine/(N_disk*mc*(x01));
W_DL             = (vt(1)-ut(1))/ut(1);
X_DL             = (2*b*mc)/(pi*mu(i)*R02^2);
expansion        = rho1/pho(i);

if W_turbine < 0
elseif W_turbine > 0
else
    W_turbine=0
end
end
```

ภาคผนวก ง

ผลของขนาดที่เหมาะสมของเทสลาเทอร์ไบนสำหรับสารทำงานทดแทน R245fa บริสุทธิ์

จากผลการประเมินการหาสารสารทำงานทดแทน R245fa บริสุทธิ์ในโรงไฟฟ้าวัฏจักรทีแอลซีที่ใช้เทสลาเทอร์ไบน์ โดยผลของขนาดและการทำงานที่เหมาะสมของเทสลาเทอร์ไบน์แสดงดังตารางที่ ง.1

ตารางที่ ง.1 ผลของขนาดและการทำงานที่เหมาะสมของเทสลาเทอร์ไบน์ของสารทำงานแต่ละชนิด

สารทำงาน	อัตราส่วนโดยมวล	D_5 (mm)	PR	ความเร็ว (RPM)
R1233zd(E)/R1336mzz(Z)	0.00/1.00*	116.72	0.84	3,000
	0.25/0.75	106.68	0.84	3,000
	0.50/0.50	102.66	0.84	3,000
	0.75/0.25	104.67	0.84	3,000
	1.00/0.00**	80.56	0.75	3,500
R1233zd(E)/R1234ze(E)	0.00/1.00***	100.65	0.71	4,500
	0.25/0.75	98.64	0.75	4,500
	0.50/0.50	122.75	0.75	4,500
	0.75/0.25	86.59	0.75	4,000
	1.00/0.00**	80.56	0.75	3,500
R1336mzz(Z)/R1234ze(E)	0.00/1.00***	100.65	0.71	4,500
	0.25/0.75	66.50	0.75	4,500
	0.50/0.50	86.59	0.75	4,000
	0.75/0.25	86.59	0.75	3,500
	1.00/0.00*	116.72	0.84	3,000
R245fa บริสุทธิ์		104.00	0.75	4,000
หมายเหตุ	* คือ R1336mzz(Z) บริสุทธิ์			
	** คือ R1336mzz(Z) บริสุทธิ์			
	*** คือ R1234ze(E) บริสุทธิ์			

โดยขนาดที่และการทำงานของเทสลาเทอร์ไบน์ที่เหมาะสมขึ้นอยู่กับคุณสมบัติและความเป็นไอของสารทำงานก่อนเข้าเทสลาเทอร์ไบน์ส่งผลให้ที่แต่ละสารทำงานมีค่าแตกต่างกันออกไป โดยที่มาของค่าที่เหมาะสมได้ทำการอภิปรายและวิเคราะห์ไว้ในบทที่ 4 และ 5

ภาคผนวก จ
ผลของขนาดที่เหมาะสมของเทสลาเทอร์ไบนสำหรับโรงของโรงไฟฟ้า แต่ละวัฏจักร

จากผลการประเมินการหาเปรียบเทียบโรงไฟฟ้าวัฏจักรต่าง ๆ ที่ใช้เทสลาเทอร์ไบน์ โดยผลของขนาดและการทำงานที่เหมาะสมของเทสลาเทอร์ไบน์แสดงดังตารางที่ ช.1

ตารางที่ จ.1 ผลของขนาดและการทำงานที่เหมาะสมของเทสลาเทอร์ไบน์ของโรงไฟฟ้าแต่ละวัฏจักร

<table>
<tr><td colspan="2">วัฏจักร</td><td>KCS-11</td><td>Mod. KCS-11</td><td colspan="2">ทีแอลซี</td></tr>
<tr><td rowspan="3">ตัวแปร</td><td rowspan="3">หน่วย</td><td colspan="4">สารทำงาน</td></tr>
<tr><td colspan="2" rowspan="2">ammonia/water 0.9/0.1</td><td rowspan="2">R236ea</td><td>R1336mzz(Z)/</td></tr>
<tr><td>R1234ze(E) 0.25/0.75</td></tr>
<tr><td>ω</td><td>RPM</td><td>14,500</td><td>10,000</td><td>3,600</td><td>4,500</td></tr>
<tr><td>PR</td><td>-</td><td>0.55</td><td>0.62</td><td>0.80</td><td>0.76</td></tr>
<tr><td>D_5</td><td>mm</td><td>84</td><td>55</td><td>94</td><td>80</td></tr>
</table>

โดยขนาดที่และการทำงานของเทสลาเทอร์ไบน์ที่เหมาะสมขึ้นอยู่กับคุณสมบัติและความเป็นไอของสารทำงานก่อนเข้าเทสลาเทอร์ไบน์ส่งผลให้ที่แต่ละสารทำงานมีค่าแตกต่างกันออกไป โดยที่มาของค่าที่เหมาะสมได้ทำการอภิปรายและวิเคราะห์ไว้ในบทที่ 4 และ 5