UNIVERSITAT POLITÈCNICA DE CATALUNYA
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Estudi pel desenvolupament d'una metodologia d'aprenentatge basat en projectes a l'assignatura de Disseny d'Avions

Document:
Annexos

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TREBALL DE FI D'ESTUDIS

Índex

A. Codis MatLab

A.1 Diagrama d'actuacions i dimensionat inicial

```
clc; clear; close all;

%% ACTUACIONS
% Distancia de take-off
k = 37.5*(0.3048/1)^3*(1/4.4482); % m^3/N
sigma = 1; % Ratio de densitat
CL_max_TO = 2.2; % [1.6 - 2.2]
s_toFL = 2400; % Distancia enlairament
W_S = 10:8000;
T_W_TO = (k) * (W_S/(sigma*CL_max_TO*s_toFL));

% Distancia aterratge
sigma = 1; % Ratio de densitat
V_SL = 204/3.6; % Velocitat entrada en perdua
V_A = 1.3*V_SL; % Velocitat aproximacio
S_lFL = V_A^2*(0.3455); % Distancia aterratge
CL_max_L = 2.8; % [1.8 - 2.8]
W_L_W_TO = 0.84; % Ratio entre pesos aterratge i enlairament
W_S_L = 1.0490 * (W_L_W_TO)^-1 * sigma * CL_max_L * S_lFL;
W_S_L_aux = [W_S_L W_S_L];
T_w_L = [0 7.5];

% Pujada en 2n segment amb fallada critica de motor
CGR = 0.027; % Pendent ascens
N_e = 2; % Numero de motors
AR = (35.8^2/122.6+35.9^2/127)/2; % Allargament
e = 0.8; % Eficiencia Oswald
CD_0 = 0.015 + 0.01; % Coeficient de resistencia parasita +0.01 per flaps
CD = CD_0 + CL_max_TO^2/(pi*AR*e); % Corba de resistencia polar
T_W_cl = N_e/(N_e-1)*(CD/CL_max_TO+CGR);
T_W_cl_aux = [T_W_cl T_W_cl];
W_S_cl_aux = [W_S(1) W_S(end)];

% Creuer
T_to = 0.928; % Regim de potencia dels motors enlairament
T_cr = 0.5; % Regim de potencia dels motors creuer
W_to = 8.846493139690951e+04; % Pes enlairament
W_cr = W_to*0.99*0.99*0.995*0.98; % Pes en creuer
rho_cr = 0.3636496; % Densitat aire a h = 11 km
Temp_cr = 216.65; % Temperatura aire a h = 11 km
V_cr = 0.78*sqrt(1.4*216.65*287); % Velocitat en creuer
CD_0 = 0.015; % Coeficient de resistencia parasita
T_W_cr = zeros(1,length(W_S));
for i = 1:length(W_S)
    T_W_cr(i) =
(T_to/T_cr)*(W_cr/W_to)*((0.5*rho_cr*V_cr^2)/(W_S(i)*W_cr/W_to))*(CD_0 +
((W_S(i)*W_cr/W_to)^2)/((0.5*rho_cr*V_cr^2)^2*pi*AR*e));
end

% Pujada accelerada
ROC = 24; % ascens a 250 km/h amb angle de 20 deg
LD = 19; % Igual que pel calcul del rang
T_W_pa = zeros(1,length(W_S));
for i = 1:length(W_S)
    T_W_pa(i) = ROC/sqrt(2/1.225*W_S(i))*(pi*AR*e*CD_0)^(1/4)+1/(LD);
end
```

```
%% AERONAUS SIMILARS
% B737 design point
B_W = 82200*9.81; % Pes
B_T_to = 119150*2*T_to; % Thrust enlairament
B_WA  = 127; % Superficie alar
B_T_W = B_T_to / B_W;
B_W_S = B_W / B_WA;

% A320 design point
A_W = 79000*9.81; % Pes
A_T_to = 130290*2*T_to; % Thrust enlairament
A_WA  = 122.7; % Superficie alar
A_T_W = A_T_to / A_W;
A_W_S = A_W / A_WA;

%% MOTORS
% LEAP 1A24
T_1A24 = 106800;
L1A24 = T_to*T_1A24*N_e/(W_to*9.81);
% LEAP 1A29
T_1A29 = 130290;
L1A29 = T_to*T_1A29*N_e/(W_to*9.81);
% PW1127G JM
T_PW11 = 120.43e3;
PW11 = T_to*T_PW11*N_e/(W_to*9.81);

%% DIAGRAMA
figure
plot(W_S,T_W_TO,'r',W_S_L_aux,T_w_L,'blue')
hold on;
plot(W_S,T_W_cr,'Color','#f78102');
hold on;
plot(W_S,T_W_pa,'green');
plot(W_S_cl_aux,T_W_cl_aux,'black',B_W_S,B_T_W,'d',A_W_S,A_T_W,'d',6166,0.279,'d'
);
grid;
grid minor;
xlim([0 8000]);
ylim([0 1]);
yline(L1A24,'--','LineWidth',2,'Color','#326b00');
yline(L1A29,'-.','LineWidth',2,'Color','#4DBEEE');
yline(PW11,':','LineWidth',3,'Color','#7E2F8E');
legend('Enlairament','Aterratge','Creuer','Pujada accelerada','2n segment','B737
MAX 8','A320neo','Punt de disseny','LEAP-1A24','LEAP-1A29','PW1127G-JM');
set(gca,'fontname','serif','fontsize',28)
ylabel('T_{to}/W_{to}');
xlabel('W_{to}/S_{W} [N/m^2]');
set(findall(gca, 'Type', 'Line'),'LineWidth',1.5);
x0=10;
y0=10;
width=1080;
height=720;
set(gcf,'position',[x0,y0,width,height]);
```

A.2 Estimació de pesos i diagrama pesos-abast

```
clc; clear; close all

%% DADES
hw = 77; %kg/p
pax = 179;
paxLug = 15; %kg/p

rhoLug = 340; %kg/m^3
rhoPallet = 150; %kg/m^3
R_cruise = 6480e3; %Rang

MTOW_a320 = 79000;
OEW_a320 = 44300;
a_a320 = OEW_a320/MTOW_a320;
MZFW_a320 = 64300;
MFW_a320 = 22000;
MPL_a320 = 20000;
MTOW_b737 = 82200;
OEW_b737 = 45070;
a_b737 = OEW_b737/MTOW_b737;
MZFW_b737 = 65950;
MFW_b737 = 21150;
MPL_b737 = 20880;

%% PESOS

MPL = pax*(hw + paxLug) + (0.85*(44 + 43.7)/2 - (pax*paxLug/rhoLug))*rhoPallet;

MTOW_a = MPL/(1-(OEW_a320/MTOW_a320) - (1 - MZFW_a320/MTOW_a320));
MTOW_b = MPL/(1-(OEW_b737/MTOW_b737) - (1 - MZFW_b737/MTOW_b737));
MTOW = (MTOW_a + MTOW_b)/2;

a = (a_a320 + a_b737)/2;
OEW = a*MTOW;

convergence = false; % Loop per convergir MTOW i FW
t = 3/4; % 45 min espera
while convergence == false
    FW = FuelCruise(MTOW, t, R_cruise);
    MTOW_new = FW + OEW + MPL;
    if MTOW_new-MTOW <=1e-6
        convergence = true;
    end
    MTOW = MTOW_new;
end

TF = FuelCruise(MTOW, 0,R_cruise);
RF = FW - TF;

beta_a = MFW_a320/MTOW_a320;
beta_b = MFW_b737/MTOW_b737;
beta = (beta_a + beta_b)/2;
MFW = MTOW*beta;

%% DIAGRAMA PES ABAST

oewRange = OEW + RF;
range = ObtainRange(oewRange, MPL, TF);
range1 = ObtainRange(oewRange, MPL-(MFW-FW), MFW-RF);
mplFinal = 0;
range2 = ObtainRange(oewRange, mplFinal, MFW-RF);
rangeFigure = [0,range,range1,range2];
rangeFigure = rangeFigure/1000;
```

```
fwFigure = [MPL + OEW + RF, MPL + OEW + RF + TF MTOW, MTOW - (MPL - MFW + FW)];
fwFigure = fwFigure/1000;

oewFigure = OEW*ones(1,4)/1000;
mtowFigure = MTOW*ones(1,4)/1000;
mplFigure = [OEW + MPL,OEW + MPL,OEW + MPL - (MFW - FW), OEW];
mplFigure = mplFigure/1000;
rfFigure = [MPL + OEW + RF,OEW + MPL + RF, OEW + MPL + RF - (MFW - FW), OEW +
RF];
rfFigure = rfFigure/1000;
plot(rangeFigure,fwFigure, 'LineWidth', 2);
hold on
plot(rangeFigure, mplFigure, 'LineWidth', 2);
plot(rangeFigure, rfFigure, 'LineWidth', 2);
plot(rangeFigure, oewFigure, 'LineWidth', 2);
plot(rangeFigure, mtowFigure, '--', 'LineWidth', 2);
rmpl = [18e4 0]/1000;
rmpl1 = [range range]/1000;
plot(rmpl1, rmpl, '-.', 'LineWidth', 2);
rmfw = [18e4 0]/1000;
rmfw1 = [range1 range1]/1000;
plot(rmfw1, rmfw, '-.', 'LineWidth', 2);
rmax = [18e4 0]/1000;
rmax1 = [range2 range2]/1000;
plot(rmax1, rmax, '-.', 'LineWidth', 2);
xlabel ('Abast [km]');
ylabel ('Massa [t]');
legend('Massa total','OEW + PL','OEW + PL + RF','OEW', 'MTOW', 'R_{MPL}',
'R_{MFW}', 'R_{MAX}','Location','northeast');
set(gca,'fontname','serif','fontsize',28);
xlim([0 9000])
ylim([25 100])
grid on;
grid minor;


%% FUNCIONS

function [R] = ObtainRange(OEW, PL, FW)

%Totes les dades han sigut extretes del llibre de Jan Roskam citat a la
%bibliografia

M = 0.78;
g = 9.81;
W0 = FW + OEW + PL;
W1 = 0.99 * W0; %Despres encesa i escalfament motors
W2 = W1 * 0.99; %Despres taxi
W3 = W2 * 0.995; %Despres enlairament
W4 = W3 * 0.98; %Despres pujada
c = sqrt(1.4*287*(216.65)); %Velocitat del so en m/s en creuer
V_cruise = c*M; %Mach en m/s

LD_cruise = 19; %Eficiencia en creuer
cj_cruise = 0.5*0.453592/3600/4.44822; %Consum de combustible de lb/lbf/hr a
kg/Ns
W8 = OEW + PL; %Despres aterratge
W7 = W8 / 0.992; %Despres descens
W6 = W7 / 0.99; %Despres espera

W5 = W6; % Despres creuer

R = V_cruise/(cj_cruise*g) * LD_cruise * log(W4/W5);

end
```

```
function [FW] = FuelCruise(MTOW, t, R_cruise)

%Totes les dades han sigut extretes del llibre de Jan Roskam citat a la
%bibliografia

M = 0.78;
g = 9.81;
W0 = MTOW;
W1 = 0.99 * W0; %Despres encesa i escalfament motors
W2 = W1 * 0.99; %Despres taxi
W3 = W2 * 0.995; %Despres enlairament
W4 = W3 * 0.98; %Despres pujada
c = sqrt(1.4*287*(216.65)); %Velocitat del so en m/s en creuer
V_cruise = c*M; %Mach en m/s

LD_cruise = 19; %Eficiencia en creuer
cj_cruise = 0.5*0.453592/3600/4.44822; %Consum de combustible de lb/lbf/hr a
kg/Ns

W5 = W4*exp(-R_cruise*cj_cruise*g/(V_cruise*LD_cruise));

E_ltr = 3600*t; % 45 min espera
cj_ltr = 0.4*0.453592/4.44822/3600; %Consum especific de combustible en kg/Ns
LD_ltr = 19; % Eficiencia en espera
W6 = W5*exp(-E_ltr * cj_ltr * g/LD_ltr); %Despres espera
W7 = W6 *0.99; %Despres descens
W8 = W7 * 0.992; %Despres taxi, aterratge i shutdown

FF = 1 - W8/W7 * W7/W6 * W6/W5 * W5/W4 * W4/W3 * W3/W2 * W2/W1 * W1/W0; %Fuel
Fraction
FW = FF*W0; %Fuel Weight
end
```

A.3 Estimació de la corba polar

```
clc; clear; close all

%% CORBA POLAR
C_L = -0.5:0.001:2.8; % Vector CL

C_D0 = 0.015; % Coef resistencia parasita
A = 10.3; % Allargament
e = 0.8; % Eficiencia Oswald

C_D = zeros(length(C_L),1);
for ii = 1:length(C_L) % Loop per calcular CD per cada CL
    if C_L(ii) > 2 % Efecte dels flaps
        C_D0 = 0.025;
    end
    C_D(ii) = C_D0 + C_L(ii)^2/(pi*A*e); % Corba polar
end

plot(C_L, C_D)
grid;
grid minor;
set(gca,'fontname','serif','fontsize',28)
xlabel('C_L');
ylabel('C_D');
set(findall(gca, 'Type', 'Line'),'LineWidth',1.5);
title('C_D(C_L)');
```