**Solution proposal : Training exercise 10.1**.

**Task 1**

The task is similar to previous investigation of tubing head pressure variations and is solved by simple modifications to the script then used. A such modified script is listed below. It provides

1. **Bottom well**

 Mean pressure: 123.9252bar Standard deviation: 0.062376

1. **Estimated distribution of downhole pressure measurement.**

Estimated cumulative distribution



Variation of downhole pressure measurement seems to follow the normal distribution

1. **Downhole pressure-, compared to tubing head pressure variation:**

Estimates at tubing head: 28.6415bar Standard deviation: 0.12389

Estimated cumulative tubing head pressure distribution:



Observations: Downhole and tubing head pressure measurement seem both to follow normal distributions.

The downhole mean pressure is much larger, as would also be predicted steady-state pipe flow calculation.

The standard deviation is 50% smaller downhole than at the tubing head. This is not is not predicted by steady-state pipe flow calculation.

**Script 1a**

disp('Plot: tubing head pressure')

clear

clf

delt=1; % time between measurements (minutes)

load DataJan2016.txt

data=DataJan2016;

ant=size(data); ntot=ant(1); % antall målepunkter

 % Time-interval

n1=1; n2=100;

pth=data(n1:n2,3);

 t1=delt\*n1;

 t2=delt\*n2;

 tp=delt\*n1:delt:delt\*n2; % time logged

 ntp=length(tp);

 stdtp(1:ntp)=mean(pth)+std(pth);

 stdtm(1:ntp)=mean(pth)-std(pth);

 meant(1:ntp)=mean(pth);

 disp([' Midlet utløpstrykk: ',num2str(mean(pth)),'(Sm^3/d) Standardavvik: ',num2str(std(pth)) ])

 subplot(2,1,1)

 hold on

 plot(tp,pth,'r.')

 plot(tp,meant,'k-')

 plot(tp,stdtp,'b-.')

 plot(tp,stdtm,'b-.')

 hold off

 legend('Measurements','Mean value','Standard deviation')

 grid

 xlabel('\bf Time (minutes)')

 ylabel('\bf p\_{th} (bar)')

 % Downhole

 pw=data(n1:n2,5);

 stdtp(1:ntp)=mean(pw)+std(pw);

 stdtm(1:ntp)=mean(pw)-std(pw);

 meant(1:ntp)=mean(pw);

 disp([' Midlet nedihullstrykk: ',num2str(mean(pw)),'(Sm^3/d) Standardavvik: ',num2str(std(pw)) ])

 subplot(2,1,2)

 hold on

 plot(tp,pw,'r.')

 plot(tp,meant,'k-')

 plot(tp,stdtp,'b-.')

 plot(tp,stdtm,'b-.')

 hold off

 legend('Measurements','Mean value','Standard deviation')

 grid

 xlabel('\bf Time (minutes)')

 ylabel('\bf p\_{w} (bar)')

**Script 1b**

disp(' Normal distribution, comparison')

clear

clf

delt=1.;

load DataJan2016.txt

data=DataJan2016;

ant=size(data);

disp(['No. of data points in file: ',num2str(ant(1))])

 % Tidsinterval

n1=1;

n2=ant;

pth=data(n1:n2,3);

pw=data(n1:n2,5);

 tp=delt\*n1:delt:delt\*n2;

 ntp=length(tp);

disp(['No. of data points ',num2str(ntp)])

%--------------------tubing head -------------------

disp(' Tubing head ')

meanpth=mean(pth);

stdpth=std(pth);

disp(['Mean pressure: ',num2str(meanpth),'bar Standard deviation: ',num2str(stdpth) ])

% ----------------------- Cummulative distribution -----------------------

pths=sort(pth);

 Femp=1:1:ntp;

 Femp=Femp/ntp;

% normalfordeling

 Fn = normcdf(pths,meanpth,stdpth);

 subplot(2,1,1)

 hold on

 plot(pths,Femp,'r.')

 plot(pths,Fn,'b')

plot([meanpth,meanpth],[0,1],'k-.')

 plot([meanpth+stdpth,meanpth+stdpth],[0,1],'g-.')

 plot([meanpth-stdpth,meanpth-stdpth],[0,1],'g-.')

 hold off

 legend('Measurements','N-distribution: F(p\_{th})','Mean','Standard deviation')

 xlabel('\bfTubing head pressure (bar)')

 ylabel('\bfCumulative')

 grid

 %

 % - bottom well

 disp(' Bottom well ')

 meanpw=mean(pw);

 stdpw=std(pw);

 disp(['Mean pressure: ',num2str(meanpw),'bar Standard deviation: ',num2str(stdpw)])

pws=sort(pw);

 Femp=1:1:ntp;

 Femp=Femp/ntp;

% normalfordeling

 Fn = normcdf(pws,meanpw,stdpw);

 subplot(2,1,2)

 hold on

 plot(pws,Femp,'r.')

 plot(pws,Fn,'b')

plot([meanpw,meanpw],[0,1],'k-.')

 plot([meanpw+stdpw,meanpw+stdpw],[0,1],'g-.')

 plot([meanpw-stdpw,meanpw-stdpw],[0,1],'g-.')

 hold off

 legend('Measurements','N-distribution: F(p\_{w})','Mean','Standard deviation')

 xlabel('\bf Bottom hole pressure (bar)')

 ylabel('\bfCumulative')

 grid

**Task 2**

From the data file, mean tubing head pressure, and rates of gas, oil and water can be calculated**.** Solubility and volume factors can be calculated from the black-oil model and mean velocity and fractions estimated. I got the following

1. Flow velocity at tubing head: 5.06 m/s
2. Gas, oil and water fractions: yg=0.84, yw=0.11, yo=0.05
3. Gas-continuous. Velocity so the fluids are probably fairly well mixed

**Script**

fprintf('\n Training exercise 10.2 Task 2 \n\n ')

clear

p0 = 1.01e5;

T0 = 273+15;

% -------- fluider -------

go=0.92;

gg=0.61;

gw=1.06;

Bw=1;

% tubing

d=4.778\*0.0254;

At=pi\*d^2/4;

 % Measurements

delt=1;

load DataJan2016.txt

data=DataJan2016;

ant=size(data); ntot=ant(1); % antall målepunkter

index=1:1:ntot; % numerering

tidtot=delt\*ntot;

 % Tidsrom

n1=1;

n2=ant;

 disp(['No. of measurements: ',num2str(ntot)])

 pth=(data(n1:n2,3)+1)\*1e5; % topptrykk

 Tth=data(n1:n2,4)+273;

 qo=data(n1:n2,11)/86400; % MFM oljerate

qw=data(n1:n2,12)/86400; % MFM vannrate

qg=data(n1:n2,13)/86400; % MFM gassrate

 %

 qom=mean(qo);

 qwm=mean(qw);

 qgm=mean(qg);

 pthm=mean(pth);

 Fw=qwm/qom;

 Rt=qgm/qom;

 Tthm=mean(Tth);

 disp(['Tubing head pressure: ',num2str(pthm\*1e-5),' (bar) '])

 disp(['Tubing head temperture: ',num2str(Tthm-273),' (C)' ])

 disp(['Gas rate: ',num2str(86400\*qgm\*1e-5),'\*10^5 (Sm^3/d) ' ])

 disp(['Oil rate: ',num2str(qom\*86400),' (Sm^3/d)' ])

 disp(['Water rate: ',num2str(qwm\*86400),' (Sm^3/d) ' ])

 disp(['Producingg as/oil-ratio: Rt= ',num2str(Rt)])

 %[ z ] = zfakgg( pthm,Tthm,gg,z);

 z=0.9;

Bg =1.01e5/pthm\*Tthm/(273+15)\*z;

 Rs =0.0059\*gg\*10^(2.14/go-0.00198\*Tthm)\*(0.797\*10^-5\*pthm+1.4)^1.205;

 Bo =0.9759+0.000952\*((gg/go)^0.5\*Rs+0.401\*Tthm-103)^1.2;

 Qo=Bo\*qom;

 Qw=Bw\*qwm;

 Qg=(qgm-qom\*Rs)\*Bg;

 yo=Qo/(Qw+Qo+Qg);

 yw=Qw/(Qw+Qo+Qg);

 yg=Qg/(Qw+Qo+Qg);

 vm=(Qo+Qg)/At;

 disp(['Oil fraction: yo= ',num2str(yo)])

 disp(['Water fraction: yw= ',num2str(yw)])

 disp(['Gas fraction: yg= ',num2str(yg)])

 disp(['Superficial velocity: vm= ',num2str(vm),' m/s'])