Scilab Textbook Companion for Manufacturing Science by A. Ghosh And A. K. Mallik[1]

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Book Description

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Scilab numbering policy used in this document and the relation to the above book.

Exa Example (Solved example)

Eqn Equation (Particular equation of the above book)

AP Appendix to Example(Scilab Code that is an Appednix to a particular Example of the above book)

For example, Exa 3.51 means solved example 3.51 of this book. Sec 2.3 means a scilab code whose theory is explained in Section 2.3 of the book.

Contents

List of Scilab Codes

Chapter 2

CASTING PROCESSES

Scilab code Exa 1.1 Calculation of filling time

```
clc
// Given that
h=15 // Height of spur in cm
l= 50 // Length of cast in cm
w= 25 // weidth of cast in cm
h1= 15 // Height of cast in cm
g= 981 // Acceleration due to gravity in cm/sec^2
Ag= 5 // Cross sectional area of the grate in cm^2
// Sample Problem 1 on page no. 46
printf("\n # PROBLEM 2.1 # \n")
v3= sqrt(2* g * h)
V = l*w*h1
tf1= V/(Ag*v3)
Am = l*w
tf2 = (Am/Ag)*(1/sqrt(2*g))*2*(sqrt(h) - sqrt(h-h1))
printf("\n Filling time for first design = %f sec , \
    n Filling time for second design = %f sec", tf1,
    tf2)
```

Scilab code Exa 2.2 Calculation of filling time

```
clc
// Given that
h=15 // Height of spur in cm
l= 50 // Length of cast in cm
w= 25 // weidth of cast in cm
h1= 15 // Height of cast in cm
g= 981 // Acceleration due to gravity in cm/sec^2
Ag= 5 // Cross sectional area of the grate in cm^2
Dm = 7800 // Density of molten Fe in Kg/m^3
Neta = 0.00496 // Kinetic viscosity in Kg/m-sec
theta = 90 // Angle in degree
Eq = 25 // (L/D) Equivalent
// Sample Problem 2 on page no. 53
printf("\n # PROBLEM 2.2 # \n")
v3= sqrt(2* g * h)*(10^(-2))
d= sqrt((Ag*4)/(%pi))*(10^(-2))
Re = Dm*v3*d/Neta
f = 0.0791*(Re)^(-1/4)
L=0.12 // in meter
Cd= (1+0.45+4*f*((L/d)+Eq))^(-1/2)
v3_ = Cd*v3
Re_ = (v3_/v3)*(Re)
f_ = 0.0791 *(Re_)^(-1/4)
Cd_ = (1+0.46+4*f_*(L/d + Eq))^(-1/2)
v3__ = Cd_*v3
V = l*w*h1
tf= (V/(Ag*v3__))*(10^-2)
printf("\n Filling time for first design = %f sec. "
    , tf)
```

Scilab code Exa 2.3 Calculation of time and discharge rate

```
clc
// Given that
Hi=1.2 // Initial height in m
H= 0.05 // Height in m
g= 9.81 // Acceleration due to gravity in m/sec^2
Dm = 2700 // Density of molten metal in Kg/m^3
Neta = 0.00273 // Kinetic viscosity in Kg/m-sec
d= 0.075 // Diameter in m
D = 1 // Internal diameter of ladle in m
// Sample Problem on page no. 56
printf("\n # PROBLEM 2.3 # \n")
v3= sqrt(2* g * Hi)
Re = Dm*v3*d/Neta
ef=0.075
Cd= (1+ef)^(-1/2)
ef_=0.82
Re_ = (2+ef_)^(-1/2)
v3_ = sqrt(2*g*H)
Re_ = Dm*v3_*d/Neta
At = (%pi/4)*D^2
An = (%pi/4)*d^2
Cd= 0.96
tf= (sqrt(2/g))*(At/An)*(1/Cd)*sqrt(Hi)
m = Dm*An*Cd*sqrt(2*g*Hi)
m_ = Dm*An*Cd*sqrt(2*g*Hi*0.25)
printf("\n Time required to empty the ladle = %f sec
    , \n Discharge rate are - \n Initially = %f Kg/
    sec \n When the ladle is 75 percent empty = %f Kg
    /sec. ",tf,m,m_)
```

Scilab code Exa 2.5 Calculation of solidification time

```
clc
// Given that
thetaF= 1540 // Temperature of mould face in degree centigrade
Theta0 = 28 // Initial temperature of mould in Degree centigrade
L= 272e3 // Latent heat of liquid metal in J/Kg
Dm = 7850 // Density of liquid metal in Kg/m^3
c = 1.17e+3 //Specific heat of sand in J/Kg-K
k = 0.8655 // Conductivity of sand in W/m-K
D= 1600 // Density of sand in Kg/m^3
h = 0.1 // Height in m
b = 10 // Thickness of slab in cm
r =h/2// V/A in meter
// Sample Problem 5 on page no. 66
printf("\n # PROBLEM 2.5 # \n")
lambda = (thetaF - Theta0)*(D*c)/(Dm*L)
Beta1 = 2*lambda/sqrt(%pi)
Alpha = k /(D*c)
ts1 = r^2 /((Beta1^2)*Alpha)//In sec
ts1_=ts1/3600 // In hour
Beta= poly(0,"Beta");
p=Beta^2 - lambda*(2/sqrt(%pi))*Beta -lambda/3
Beta2 = roots(p)
printf(" The value of Beta2 is %f, ",Beta2)
printf("\n We only take the positive value of Beta2, \n Hence Beta2=1.75")
r1 = r/3
ts2 = (r1^2)/((1.75^2)*Alpha) // in sec
ts2_=ts2/3600//in Hour
```

```
printf("\n\n Solidification time for slab-shaped casting = %f hr,\n Solidification time for sphere = %f hr", ts1_,ts2_)
```

Scilab code Exa 2.6 Calculation of solidification time and surface temperature

```
clc
// Given that
thetaF= 1540 // Temperature of mould face in degree centigrate
ThetaO = 28 // Initial temperature of mould in Degree centigrate
L= 272e3 // Latent heat of iron in J/Kg
Dm = 7850 // Density of iron in Kg/m^3
Cs = 0.67e+3 //Specific heat of iron in J/Kg-K
C = 0.376e3 //Specific heat of copper in J/Kg-K
Ks = 83 // Conductivity of iron in W/m-K
K = 398 // Conductivity of copper in W/m-K
D= 8960 // Density of copper in Kg/m^3
h = .1 // Height in m
// Sample Problem 6 on page no. 73
printf("\n # PROBLEM 2.6 # \n")
zeta1=0.98//By solving eqauation- zeta*exp(zeta^2)*erf(zeta)=((thetaF-thetaO)*Cs)/(sqrt(pi)*L), zeta = 0.98
AlphaS = Ks /(Dm*Cs)
ts1 = h^2 / (16*(zeta1^2) * AlphaS)//In sec
ts1_=ts1/3600 // In hour
Phi = sqrt((Ks*Dm*Cs)/(K*D*C))
zeta2=0.815//By solving eqauation- zeta*exp(zeta^2)*(erf(zeta)+Phi)=((thetaF-thetaO)*Cs)/(sqrt(pi)*L), zeta = 0.815
ts2 = h^2 / (16*(zeta2^2) * AlphaS)//In sec
```

```
ts2_=ts2/3600 // In hour
thetaS= (thetaF-(L*(sqrt(%pi))*zeta2*(exp(zeta2^2))*erf(zeta2))/Cs)
printf("\n Solidification time for slab-shaped casting when the casting is done in a water cooled copper mould = %f hr,\n Solidification time for slab-shaped casting when the casting is done in a very thick copper mould = %f hr,\n The surface temperature of the mould = %f C", ts1_,ts2_,thetaS)
```

Scilab code Exa 2.7 Calculation of solidification time and surface temperature

```
clc
// Given that
thetaF= 1540 // Temperature of mould face in degree centigrade
theta0 = 28 // Initial temperature of mould in Degree centigrade
L= 272e3 // Latent heat of iron in J/Kg
Dm = 7850 // Density of iron in Kg/m^3
Cs = 0.67e+3 //Specific heat of iron in J/Kg-K
C = 0.376e3 //Specific heat of copper in J/Kg-K
Ks = 83 // Conductivity of iron in W/m-K
K = 398 // Conductivity of copper in W/m-K
D= 8960 // Density of copper in Kg/m^3
h = .1 // Height in m
hF = 1420 // Total heat transfer coefficient across the casting-mould interface in W/m^2- C
// Sample Problem 7 on page no. 75
printf("\n # PROBLEM 2.7 # \n")
AlphaS = K /(D*C)
thetaS = 982 //In  C  as in example 2.6
```

```
h1= (1+(sqrt((Ks*Dm*Cs)/(K*D*C))))*hF
a = 1/2 + (sqrt((1/4)+Cs*(thetaF-thetaS)/(3*L)))
delta=h/2
ts = (delta+((h1*delta^2)/(2*Ks)))/((h1*(thetaF-thetaS))/(Dm*L*a)) // in sec
ts_ = ts/3600 // in hours
h2= (1+(sqrt((K*D*C)/(Ks*Dm*Cs))))*hF
gama= ((h2^2)/(K^2))*AlphaS*ts
thetaS_ = theta0 + (thetaS-theta0)*(1-((exp(gama))*(1-(erf(sqrt(gama))))))
printf("\n Solidification time = %f hr,\n  The surface temperature of the mould = %f   C", ts_, thetaS_)
// The value of the surface temperature of the mould in the book is given as 658.1   C, Which is wrong.
```

Scilab code Exa 2.8 Calculation of mould length and cooling water requirement

```
clc
// Given that
A= 60*7.5 // Cross sectional area in cm^2
v=0.05 // Withdrawal rate in m/sec
t = 0.0125 // Thickness in m
thetaF= 1500 // Temperature of mould face in degree centigrate
thetaP = 1550 //
theta0 = 20 // Initial temperature of mould in Degree centigrate
L= 268e3 // Latent heat of molten metal in J/Kg
Dm = 7680 // Density of molten metal in Kg/m^3
Cs = 0.67e+3 //Specific heat of molten metal in J/Kg-K
```

```
Cm = 0.755e3 //Specific heat of mould in J/Kg-K
Ks = 76 // Conductivity of molten metal in W/m-K
hF = 1420 // Heat transfer coefficient at the casting-mould interface in W/m^2- C
Dtheta = 10 // Maximum temperature of cooling water in   C
// Sample Problem 8 on page no. 77
printf("\n # PROBLEM 2.8 # \n")
L_ = L+Cm*(thetaP-thetaF)
x=L_ / (Cs*(thetaF-thetaO))
y= hF*t/Ks
printf(" L_/(Cs(thetaF-thetaO))=%f,\n hF*t/Ks=%f",x,y)
z=0.11 // Where z=hF^2 * lm / (v*Ks*Dm*Cs)
lm= (z*v*Ks*Dm*Cs)/(hF^2)
Z=0.28 // Where Z=Q/(lm*(thetaF-thetaO)*sqrt(lm*v*Dm*Cs*Ks))
Q = Z*lm*(thetaF-thetaO)*sqrt(lm*v*Dm*Cs*Ks)
m = Q / (4.2e3*Dtheta)
printf("\n The mould length = %f meter,\n  The cooling water requirement = %f Kg/sec", lm,m)
// Answer for The cooling water requirement in the book is given as 5.05 Kg/sec, Which is wrong.
```

Scilab code Exa 2.9 Calculation of riser volume

```
clc
// Given that
a = 15 // Side of the aluminium cube in cm
Sh = 0.065 // Volume shrinkage of aluminium during solidification
// Sample Problem 9 on page no. 81
printf("\n # PROBLEM 2.9 # \n")
```

```
Vc = a^3
Vr = 3*Sh*Vc
h = ((4*Vr)/%pi)^(1/3)
Rr = 6/h // Where Rr= (A/V)r
Rc = 6/a // Where Rc = (A/V)c
printf("(A/V)r=%f, (A/V)c=%f\n Hence Rr is greater than Rc",Rr,Rc)
dmin = 6/Rc
Vr_ = (%pi/4)*dmin^3
printf("\n With minimum value of d Vr=%d cm^3 .\n This valume is much more than the minimum Vr necessary. \nLet us now consider the top riser when the optimum cylindrical shape is obtained with h=d/2 \nand again (A/V)r = 6/d. However, with a large top riser,\n the cube loses its top surface for the purpose of heat dissipation.",Vr_)
Rc_ = 5/a
dmin_=6/Rc_
printf("\n d should be greater than or equal to %d cm",dmin_)
Vr__ = (%pi/4)*dmin_^2 *floor(h)
printf("\n The riser volume with minimum diameter is %d cm^3",Vr__)
```

Chapter 3

FORMING PROCESSES

Scilab code Exa 3.1 Calculation of strip thickness and average shear yield stress

```
clc
// Given that
A = 150*6 // Cross-section of strips in mm^2
ti = 6 // Thickness in mm
pA = 0.20 // Reduction in area
d = 400 // Diameter of steel rolls in mm
Ys = 0.35// Shear Yield stress of the material before rolling in KN/mm^2
Ys_ = 0.4// Shear Yield stress of the material after rolling in KN/mm^2
mu = 0.1 // Cofficient of friction
// Sample Problem 1 on page no. 112
printf("\n # PROBLEM 3.1 # \n")
tf =0.8*ti
Ys_a = (Ys + Ys_)/2
r=d/2
thetaI = sqrt((ti-tf)/r)
lambdaI=2*sqrt(r/tf)*atan(thetaI *sqrt(r/tf))
lambdaN = (1/2)*((1/mu)*(log(tf/ti)) + lambdaI)
thetaN  =(sqrt(tf/r))*(tan((lambdaN/2)*(sqrt(tf/r)))
)
```

```
printf("\n The final srip thickness is %f mm, \n The avg shear yield stress during the process is %f KN/mm^2, \n The angle subtended by the deformation zone at the roll centre is %f rad, \n The location of neutral point is %f rad.",tf,Ys_a,thetaI,thetaN)
```

Scilab code Exa 3.2 Calculation of roll separating force and power required in the

```
clc
// Given that
A = 150*6 // Cross-section of strips in mm^2
w = 150 // Width of the strip in mm
ti = 6 // Thickness in mm
pA = 0.20 // Reduction in area
d = 400 // Diameter of steel rolls in mm
Ys = 0.35// Shear Yield stress of the material before rolling in KN/mm^2
Ys_ = 0.4// Shear Yield stress of the material after rolling in KN/mm^2
mu = 0.1 // Cofficient of friction
v = 30 // Speed of rolling in m/min
// Sample Problem 2 on page no. 113
printf("\n # PROBLEM 3.2 # \n")
tf =0.8*ti
Ys_a = (Ys + Ys_)/2
r=d/2
thetaI = sqrt((ti-tf)/r)
lambdaI=2*sqrt(r/tf)*atan(thetaI *sqrt(r/tf))
lambdaN = (1/2)*((1/mu)*(log(tf/ti)) + lambdaI)
thetaN =(sqrt(tf/r))*(tan((lambdaN/2)*(sqrt(tf/r)))
)
Dtheta_a = thetaN/4
```

```
Dtheta_b = (thetaI- thetaN)/8
printf("The values of P_after are\n")
i = 0
for i = 0:4
    theta = i*Dtheta_a
    y = (1/2)* (tf+r*theta^2)
    lambda = 2*sqrt(r/tf)*atand(theta*(%pi/180) * sqrt(r/tf))
    p_a = 2*Ys_a*(2*y/tf)*(exp(mu*lambda))
    printf("%f \n",p_a)
end
I1 = (Dtheta_a/3) *(0.75+.925+4*(.788+.876)+2*.830) // By Simpson's rule
printf("The values of P_before are\n")
for i = 0:8
    theta1 = i*Dtheta_b + thetaN
    y = (1/2)* (tf+r*theta1^2)
    lambda = 2*sqrt(r/tf)*atand(theta1*(%pi/180) * sqrt(r/tf))
    p_b = 2*Ys_a*(2*y/ti)*(exp(mu*(lambdaI-lambda)))
    printf(" %f \n",p_b)
end
I2 = (Dtheta_b/3)*(0.925+.75+4*(.887+.828+.786+.759) + 2*(.855+.804+.772))//By Simpson's rule
F = r*(I1 + I2)
F_ = F*w
T = (r^2)*mu*(I2-I1)
T_ =T*w
W = v*(1000/60)/r
P = 2*T_*W
printf("\n The roll separating force = %d kN,\n The power required in the rolling process = %f kW", ceil(F_),P/1000)
// Answer in the book for the power required in the rolling process is given as 75.6 kW
```

Scilab code Exa 3.3 Calculation of mill power

```
clc
// Given that
A = 150*6 // Cross-section of strips in mm^2
w = 150 // Width of the strip in mm
ti = 6 // Thickness in mm
pA = 0.20 // Reduction in area
d = 400 // Diameter of steel rolls in mm
Ys = 0.35// Shear Yield stress of the material before rolling in KN/mm^2
Ys_ = 0.4// Shear Yield stress of the material after rolling in KN/mm^2
mu = 0.1 // Cofficient of friction
mu_ = 0.005 // Cofficient of friction in bearing
D = 150 // The diameter of bearing in mm
v = 30 // Speed of rolling in m/min
// Sample Problem 3 on page no. 115
printf("\n # PROBLEM 3.3 # \n")
tf =0.8*ti
Ys_a = (Ys + Ys_)/2
r=d/2
thetaI = sqrt((ti-tf)/r)
lambdaI=2*sqrt(r/tf)*atan(thetaI *sqrt(r/tf))
lambdaN = (1/2)*((1/mu)*(log(tf/ti)) + lambdaI)
thetaN  =(sqrt(tf/r))*(tan((lambdaN/2)*(sqrt(tf/r))))
Dtheta_a = thetaN/4
Dtheta_b = (thetaI- thetaN)/8
i = 0
for i = 0:4
    theta = i*Dtheta_a
```

```
    y = (1/2)* (tf+r*theta^2)
    lambda = 2*sqrt(r/tf)*atand(theta*(%pi/180) *
       sqrt(r/tf))
    p_a = 2*Ys_a*(2*y/tf)*(exp(mu*lambda))
end
I1 = (Dtheta_a/3) *(0.75+.925+4*(.788+.876)+2*.830)
for i = 0:8
    theta1 = i*Dtheta_b + thetaN
    y = (1/2)* (tf+r*theta1^2)
    lambda = 2*sqrt(r/tf)*atand(theta1*(%pi/180) *
       sqrt(r/tf))
    p_b = 2*Ys_a*(2*y/ti)*(exp(mu*(lambdaI-lambda)))
end
I2 = (Dtheta_b/3)*(0.925+.75+4*(.887+.828+.786+.759)
    + 2*(.855+.804+.772))
F = r*(I1 + I2)
F_ = F*w
T = (r^2)*mu*(I2-I1)
T_ =T*w
W = v*(1000/60)/r
P_ = 2*T_*W
P1 = mu_*F_*D*W
P = P1+P_
printf("\n The mill power = %f kW",P/1000)
// Answer in the book is given as 79.18 kW
```

Scilab code Exa 3.4 Calculation of maximum forging force

```
clc
// Given that
mu = 0.25 // Cofficient of friction between the job
   and the dies
Y = 7 // Avg yield stress of the lead in N/mm^2
```

```
h = 6 // Height of die in mm
L = 150 // Length of the strip in mm
V1 = 24*24*150 // Volume of the strip in mm^3
V2 = 6*96*150 // Volume of the die in mm^3
w= 96 // Weidth of the die in mm
// Sample Problem 4 on page no. 118
printf("\n # PROBLEM 3.4 # \n")
K = Y/sqrt(3)
x_ = (h/(2*mu))*(log(1/(2*mu)))
l = w/2
funcprot(0)
function p1 = f(x), p1 = (2*K)*exp((2*mu/h)*x),
endfunction
funcprot(0)
I1 = intg(0,x_,f)
function p2 = f(y), p2=(2*K)*((1/2*mu)*(log(1/(2*mu))) + (y/h)),
endfunction
I2 = intg(x_,l,f)
F = 2*(I1+I2)
F_ = F*L
printf("\n The maximum forging force = %e N",F_)
// Answer in the book is given as 0.54*10^6 N
```

Scilab code Exa 3.5 Calculation of maximum forging force

```
clc
// Given that
mu = 0.08// Cofficient of friction between the job and the dies
Y = 7 // Avg yield stress of the lead in N/mm^2
h = 6 // Height of die in mm
L = 150 // Length of the strip in mm
```

```
V1 = 24*24*150 // Volume of the strip in mm^3
V2 = 6*96*150 // Volume of the die in mm^3
w= 96 // Weidth of the die in mm
// Sample Problem 5 on page no. 119
printf("\n # PROBLEM 3.5 # \n")
K = Y/sqrt(3)
x_ = (h/(2*mu))*(log(1/(2*mu)))
l = w/2
funcprot(0)
function p1 = f(x), p1 = (2*K)*exp((2*mu/h)*x),
endfunction
I = intg(0,l,f)
F = 2*(I)
F_ = F*L
printf("\n The maximum forging force = %e N",F_)
```

Scilab code Exa 3.6 Calculation of maximum forging force

```
clc
// Given that
r = 150 // Radius of the circular disc of lead in mm
Ti = 50 // Initial thickness of the disc in mm
Tf = 25 // Reduced thickness of the disc in mm
mu = 0.25// Coefficient of friction between the job
   and the dies
K = 4 // Avg shear yield stress of the lead in N/mm
   ^2
// Sample Problem 6 on page no. 122
printf("\n # PROBLEM 3.6 # \n")
R = r*sqrt(2)
rs = (R - ((Tf/(2*mu)) * log(1/(mu*sqrt(3)))))
funcprot(0)
function p1 = f(x), p1 = (((sqrt(3))*K)*exp((2*mu/Tf
```

```
)*(R-x)))*x,
endfunction
I = intg(rs,R,f)
funcprot(0)
function p2 = f(y), p2 = ((2*K/Tf)*(R-y) + ((K/mu)*(1+log(mu*sqrt(3)))))*y,
endfunction
I_ = intg(0,rs,f)
F = 2*%pi*(I+I_)
printf("\n The maximum forging force = %e N",F)
```

Scilab code Exa 3.7 Calculation of drawing power and maximum passible reduction in

```
clc
// Given that
Di = 12.7 // Intial diameter in mm
Df = 10.2 // Final diameter in mm
v = 90 // Drawn speed in m/min
alpha=6 // Half angle of dia in degree
mu = 0.1// Cofficient of friction between the job and the dies
Y = 207 // Tensile  yield stress of the steel specimen in N/mm^2
Y_ = 414 // Tensile yield stress of the similar specimen at strain 0.5 in N/mm^2
e = 0.5 // Strain
// Sample Problem 7 on page no. 126
printf("\n # PROBLEM 3.7 # \n")
e_ =2* log(Di/Df)
Y_e = Y + (Y_ - Y)*e_/e
Y__ = (Y+Y_e)/2
phi = 1 + (mu/tand(alpha))
Y_f = Y__ * ((phi/(phi-1)) *(1-((Df/Di)^(2*(phi-1)))
```

```
))
p = Y_f * (%pi/4)*(Df^2)*v/60
Dmax = 1- (1/(phi^(1/(phi-1))))
printf("\n Drawing power = %f kW, \n The maximum passible reduction with same die = %f mm",p/1000,Dmax)
```

Scilab code Exa 3.8 Calculation of drawing force and minimum passible radius of th

```
clc
// Given that
Ri = 30 // Inside radius of cup in mm
t = 3 // Thickness in mm
Rb = 40 // Radius of the blank in mm
K = 210 // Shear yield stress of the material in N/mm^2
Y = 600 // Maximum allowable stress in N/mm^2
Beta = 0.05
mu = 0.1// Cofficient of friction between the job and the dies
// Sample Problem 8 on page no. 130
printf("\n # PROBLEM 3.8 # \n")
Fh = Beta*%pi*(Rb^2)*K
Y_r = (mu*Fh/(%pi*Rb*t))+(2*K*log(Rb/Ri))
Y_z = Y_r*exp(mu*%pi/2)
F = 2*%pi*Ri*t*Y_z
Y_r_ = Y/exp(mu*%pi/2)
Rp = (Rb/exp((Y_r_/(2*K)) - ((mu*Fh)/(2*%pi*K*Rb*t))))-t
printf("\n Drawing force = %d N, \n Minimum passible radius of the cup which can drawn from the given blank without causing a fracture = %f mm",F,Rp)
// Answer in the book given as 62680 N
```

Scilab code Exa 3.9 Calculation of maximum bending force and required punch angle

```
clc
// Given that
L_ = 20 // Length of the mild steel product in mm
h = 50 // Height of the mild steel product in mm
L = 50 // Horizontal length of the mild steel product in mm
t = 5 // Thickness in mm
l=25 // Length of the bend in mm
E = 207 // Modulus of elasticity in kN/mm^2
n = 517 // Strain hardening rate in N/mm^2
Y = 345 // Yield stress in N/mm^2
mu = 0.1// Cofficient of friction
e = 0.2 // Fracture strain
theta = 20 // Bend angle in degree
// Sample Problem 9 on page no. 135
printf("\n # PROBLEM 3.9 # \n")
Rp = ((1 /((exp(e) - 1)))-0.82)*t/1.82
Y_1 = Y+n*e
Y_2 = Y + n*(log(1+(1/(2.22*(Rp/t)+1))))
M = ((0.55*t)^2)*((Y/6)+(Y_1/3)) + ((0.45*t)^2)*((Y/6)+(Y_2/3))
Fmax = (M/l)*(1+(cosd((atand(mu))+mu*sind(atand(mu))))))
Fmax_ = L_*Fmax
alpha = 90 /((12*(Rp+0.45*t)*M/(E*(10^3)*(t^3)))+1)
Ls = 2*(((Rp+0.45*t)*%pi/4) + 50-(Rp+t))
printf("\n Maximum bending force = %d N, \n The required puch angle = %f ,\n The stock length = %f mm",Fmax_,alpha,Ls)
// Answer in the book for maximum bending force is
```

```
given as 4144 N
```

Scilab code Exa 3.10 Calculation of minimum value of die length and minimum requir

```
clc
// Given that
L_ = 20 // Length of the mild steel product in mm
h = 50 // Height of the mild steel product in mm
L = 50 // Horizontal length of the mild steel product in mm
t = 5 // Thickness in mm
l=25 // Length of the bend in mm
E = 207 // Modulus of elasticity in kN/mm^2
n = 517 // Strain hardening rate in N/mm^2
Y = 345 // Yield stress in N/mm^2
mu = 0.1// Cofficient of friction
e = 0.2 // Fracture strain
theta = 20 // Bend angle in degree
F = 3000 // Maximum available force in N
// Sample Problem 10 on page no. 136
printf("\n # PROBLEM 3.10 # \n")
Rp = ((1 /((exp(e) - 1)))-0.82)*t/1.82
Y_1 = Y+n*e
Y_2 = Y + n*(log(1+(1/(2.22*(Rp/t)+1))))
M = ((0.55*t)^2)*((Y/6)+(Y_1/3)) + ((0.45*t)^2)*((Y/6)+(Y_2/3))
Fmax = (M/l)*(1+(cosd((atand(mu))+mu*sind(atand(mu))))))
Fmax_ = L_*Fmax
lmin  = Fmax_*l/F
Ls = 2*(((Rp+0.45*t)*%pi/4) + 50-(Rp+t))
lmax = Ls / 2
Fmax_min  = Fmax_*l/lmax
```

```
printf("\n Minimum value of die length = %f mm, \n Minimum required capacity of the machine = %d N", lmin,ceil(Fmax_min))
// Answer in the book is give as 2323 N for Minimum required capacity of the machine
```

Scilab code Exa 3.11 Calculation of maximum force required for extruding the bille

```
clc
// Given that
d = 50 // Diameter of the billet in mm
L =75 // Length of the billet in mm
D = 10 // Final diameter of billet in mm
Y = 170 // Avg tensile yield stress for aluminium in N/mm^2
mu = 0.15 // Cofficient of the friction
// Sample Problem 11 on page no. 141
printf("\n # PROBLEM 3.11 # \n")
l = L - ((d-D)/2)*cotd(45)
phi = 1+mu
Y_x = Y*(phi/(phi-1))*(((d/D)^(2*(phi-1)))-1)
F = (%pi/4)*(d^2)*Y_x + (%pi/sqrt(3))*(d*l*Y)
Pf = %pi*Y*(d^2)*((phi/(2*mu))*(((d/D)^(2*mu))-1)-log(d/D)) + (%pi/sqrt(3))*Y*d*l
Loss_f = (Pf/F)*100
Y_X = Y*4.31*log(d/D)
F_ = (%pi/4)*(d^2)*Y_X + (%pi/sqrt(3))*(d*l*Y)
Pf_1 = (%pi/sqrt(3))*Y*(d^2)*(log(d/D))
Pf_2 = (%pi/sqrt(3))*(d*l*Y)
Pf_ = Pf_1+Pf_2
Loss_f_ = (Pf_/F_)*100
printf("\n Maximum force required for extruding the cylindrical aluminium billet = %d N, \n Percent
```

```
of the total power input will be lost in friction at the start of the operation = %f percent. ",F,Loss_f_)
// Answer in the book given as 2436444 N for max force required for extruding the cylindrical aluminium billet
```

Scilab code Exa 3.12 Calculation of proper clearance between die and punch and max

```
clc
// Given that
d = 50 // Diameter of the steel sheet in mm
t = 3 // Thickness of the steel sheet in mm
e = 1.75 // True fracture strain
Y = 2.1e3 // True fracture stress for the material in N/mm^2
// Sample Problem 12 on page no. 149
printf("\n # PROBLEM 3.12 # \n")
C_0 = (t/(1.36*exp(e)))*((2*exp(e))-1)/((2.3*exp(e))-1)
p = t*(1/2.45)*((1.9*exp(e))-1)/((2.56*exp(e))-1)
F = Y*C_0*%pi*d
W = (1/2)*(F)*(p)*(10^-3)
printf("\n The proper clearance between die and punch = %f mm, \n Maximum punching force = %f N, \n Energy required to punch the hole = %f J",C_0,F/1000,W)
// Answer in the book given as 45.74 J for energy required to punch the hole
```

Chapter 4

FORMING PROCESSES

Scilab code Exa 4.1 Calculation of shear plane angle and shear strain

```
clc
// Given that
alpha = 10 // Rake angle in Degree
t = 0.4 // Chip thickness  in mm
T = 0.15 // Uncut chip thickness in mm
// Sample Problem 1 on page no. 187
printf("\n # PROBLEM 4.1 # \n")
r = T/t
phi = atand((r*cosd(alpha))/(1-r*sind(alpha)))
gama = cotd(phi) + tand(phi-alpha)
printf("\n Shear plane angle = %f  , \n Magnitude of
    the shear strain = %f",phi,gama)
```

Scilab code Exa 4.2 Calculation of coefficient of friction and ultimate shear stre

```
clc
// Given that
```

```
t1 = 0.25 // Undercut thickness in mm
t2 = 0.75 // Chip thickness in mm
w = 2.5 // Width in mm
alpha = 0 // Rake angle in Degree
Fc = 950 // Cutting force in N
Ft = 475 // Thrust force in N
// Sample Problem 2 on page no. 192
printf("\n # PROBLEM 4.2 # \n")
r = t1/t2
mu = ((Fc*sind(alpha)) + (Ft*cosd(alpha)))/((Fc*cosd(alpha))-(Ft*sind(alpha)))
phi = atand((r*cosd(alpha))/(1-r*sind(alpha)))
As = t1*w/sind(phi)
Fs = Fc*cosd(phi) - Ft*sind(phi)
T_s = Fs/As
printf("\n Coefficient of the friction between tool and the chip = %f, \n The ultimate shear stress of the material = %f N/mm^2",mu,T_s)
```

Scilab code Exa 4.3 Calculation of shear angle and cutting and trust force

```
clc
// Given that
alpha = 10 // Rake angle of tool in Degree
v = 200 // Cutting speed in m/min
t1 = 0.2 // Uncut thickness in mm
w = 2 // Width of cut in mm
mu = 0.5 // Avg value of the cofficient of tbe friction
T_S = 400 // Shear stress of the work material in N/mm^2
// Sample Problem 3 on page no. 193
printf("\n # PROBLEM 4.3 # \n")
```

```
lambda = atand(mu)
phi = (90 + alpha - lambda)/2
Fs = (w*t1*T_S)/(sind(phi))
R = Fs/(cosd(phi+lambda-alpha))
Fc = R*(cosd(lambda-alpha))
Ft = R*(sind(lambda-alpha))
printf("\n Shear angle = %f , \n Cutting force = %d N, \n Thrust force = %d N,",phi,Fc,Ft)
// Answer in the book for cutting force is given as 420 N and for thrust force is given as 125 N
```

Scilab code Exa 4.4 Calculation of shear angle and cutting force and thrust force

```
clc
// Given that
alpha = 10 // Rake angle of tool in Degree
v = 200 // Cutting speed in m/min
t1 = 0.2 // Uncut thickness in mm
w = 2 // Width of cut in mm
mu = 0.5 // Avg value of the cofficient of tbe friction
T_S = 400 // Shear stress of the work material in N/mm^2
Cm = 70 // Machining constant in Degree
// Sample Problem 4 on page no. 194
printf("\n # PROBLEM 4.4 # \n")
lambda = atand(mu)
phi = (Cm + alpha - lambda)/2
Fs = (w*t1*T_S)/(sind(phi))
R = Fs/(cosd(phi+lambda-alpha))
Fc = R*(cosd(lambda-alpha))
Ft = R*(sind(lambda-alpha))
// Using Lee and Shaffer relation
```

```
phi_ = 45-lambda+alpha
Fs_ = (w*t1*T_S)/(sind(phi_))
R_ = Fs_/(cosd(phi_+lambda-alpha))
Fc_ = R_*(cosd(lambda-alpha))
Ft_ = R_*(sind(lambda-alpha))
printf("\n Shear angle = %f , \n Cutting force = %f
    N, \n Thrust force = %f N \n Using Lee and
   Shaffer relation− \n Shear angle = %f , \n
   Cutting force = %f N, \n Thrust force = %f N,",
   phi,Fc,Ft,phi_,Fc_,Ft_)
// Answer in the book for cutting force is given as
   486.9 N and for thrust force is given as 144.9 N
   , When using Lee and Shaffer relation answer in
   the book for cutting force is given as 481.9 N
   and for trust force is given as 160.6 N
```

Scilab code Exa 4.5 Calculation of cutting force

```
clc
// Given that
t1 = 0.25 // Uncut thickness in mm
w = 2.5 // Width of cut in mm
U_0 = 1.4 // In J/mm^3
alpha = 0 // Rake angle in degree
mu = 0.5 // Cofficient of the friction
T_s = 400 // Shear stress in N/mm^2
// Sample Problem 5 on page no. 196
printf("\n # PROBLEM 4.5 # \n")
lambda = atand(mu)
Fc = 1000*(t1*w*U_0)*((t1)^(-.4))
phi = 45 + alpha - atand(mu)
Fc_ = (w*t1*T_s*cosd(lambda-alpha))/((sind(phi)) *
   cosd(phi+lambda-alpha))
```

```
printf(" \n The order of magnitude of cutting force
    = %d N,\n Using Lee and Shaffer relation− \n The
    order of magnitude of cutting force = %d N.",Fc,
    Fc_)
// Answer in the book for cutting force is given as
    1517 N
```

Scilab code Exa 4.6 Calculation of maximum temperature along the rake face

```
clc
// Given that
v = 2 // Cutting speed in m/sec
D = 7200 // Density of mild steel in kg /m^3
k = 43.6 // Thermal conductivity in W/m− c
c = 502 // Specific heat of the material in J/kg− c
t1 = 0.25 // Uncut thickness in mm
w =2 // Width of cut in mm
theta_0 = 40 // Initial temp of the workpiece in
    Degree
alpha = 0 // Rake angle in degree
mu = 0.5 // Cofficient of the friction
T_s = 400e6 // Shear stress in N/m^2
// Sample Problem 6 on page no. 199
printf("\n # PROBLEM 4.6 # \n")
lambda = atand(mu)
phi = 45 + alpha - lambda
Fs = (w*t1*T_s)*(10^-6)/(sind(phi))
R = Fs / (cosd(phi+lambda-alpha))
Fc = R *(cosd(lambda-alpha))
r = sind(phi)/(cosd(phi-alpha))
Ft= Fc *(tand(lambda - alpha))
F = Fc *(sind(alpha))+Ft*(cosd(alpha))
Ws = F*r*v
```

```
Wp = Fc*v-F*r*v
zeta = D*c*v*t1*(10^-3)/k
zeta_ = zeta*tand(phi)
nu = 0.15 *(log(27.5/(zeta_)))
theta_P = (1-nu)*Wp/(D*c*v*t1*w*(10^-6))
theta_S = 1.13 *(sqrt(1/(D*c*v*t1*(10^-3)*k*(1+tand(phi-alpha)))))*(Ws/w)*(10^3)
theta = theta_0+theta_S+ theta_P
printf(" \n Maximum temperature along the rake face of the tool = %d C.",theta)
// Answer in the book  is given as 823 C
```

Scilab code Exa 4.7 Calculation of maximum speed at which cutting is passible

```
clc
// Given that
theta_ = 40 //Ambient temperature in C
v = 2 // Cutting speed in m/sec
D = 7200 // Density of mild steel in kg /m^3
k = 43.6 // Thermal conductivity in W/m- c
c = 502 // Specific heat of the material in J/kg- c
t1 = 0.25 // Uncut thickness in mm
w =2 // Width of cut in mm
alpha = 0 // Rake angle in degree
mu = 0.5 // Cofficient of the friction
T_s = 400e6 // Shear stress in N/m^2
H = 350 // Hardness of SAE 1040 steel in HV(Vicker hardness)
// Sample Problem 7 on page no. 206
printf("\n # PROBLEM 4.7 # \n")
lambda = atand(mu)
phi = 45 + alpha - lambda
Fs = (w*t1*T_s)*(10^-6)/(sind(phi))
```

```
R = Fs / (cosd(phi+lambda-alpha))
Fc = R *(cosd(lambda-alpha))
r = sind(phi)/(cosd(phi-alpha))
Ft= Fc *(tand(lambda - alpha))
F = Fc *(sind(alpha))+Ft*(cosd(alpha))
Ws = F*r*v
Wp = Fc*v-F*r*v
zeta = D*c*v*t1*(10^-3)/k
zeta_ = zeta*tand(phi)
nu = 0.15 *(log(27.5/(zeta_)))
Theta_0v = ((1-nu)*Wp + Ws)/ (D*c*v*t1*w*(10^-6))
H_ = 1.5 *(H)
theta_lim = 700*((1-(H_/850))^(1/3.1))
v_lim = (theta_lim/309)^(1/0.5)
printf(" \n Maximum speed at which cutting is
    passible = %f m/sec.",v_lim)
```

Scilab code Exa 4.8 Calculation of percentage increase in tool life

```
clc
// Given that
alpha = 0 // Rake angle in degree
gama = 3 // Clearance angle in Degree
w = 1 // Maximum length of flank wear allowed in mm
gama_ = 7 // Increased clearance angle in Degree
// Sample Problem 8 on page no. 212
printf("\n # PROBLEM 4.8 # \n")
I_per = (((tand(gama_))-(tand(gama)))/tand(gama))
    *100
printf(" \n Percentage increase in tool life = %d
    percent.",I_per)
```

Scilab code Exa 4.9 Calculation of three components of machining force

```
clc
// Given that
d= 4 // Depth of cut in mm
f = 0.25 // Feed in mm/stroke
alpha = 10 // Rake angle in degree
shi = 30 // Principal cutting edge angle in Degree
mu =0.6 // Cofficient of friction between chip and tool
T_s = 340 // Ultimate shear stress of cast iron in N/mm^2
// Sample Problem 9 on page no. 220
printf("\n # PROBLEM 4.9 # \n")
lambda = atand(mu)
phi = 45 +alpha-lambda
Fc = f*d*T_s*(cosd(lambda-alpha))/((sind(phi))*(cosd(phi+lambda-alpha)))
Ft = Fc*(sind(lambda-alpha))/(cosd(lambda-alpha))
Ff = Ft*(cosd(shi))
Fn = Ft*(sind(shi))
printf(" \n The three components of machinig force are as follows-\n Thrust force = %d N,\n Feed force component = %d N,\n Normal thrust force component = %d N.",Ft,Ff,Fn)
```

Scilab code Exa 4.10 Calculation of average power consumption and specific power c

```
clc
// Given that
d= 4 // Depth of cut in mm
f = 0.25 // Feed in mm/stroke
alpha = 10 // Rake angle in degree
shi = 30 // Principal cutting edge angle in Degree
mu =0.6 // Cofficient of friction between chip and
    tool
T_s = 340 // Ultimate shear stress of cast iron in N
    /mm^2
N = 60 // Cutting stroke/min
L = 200 // Length of the job in mm
H = 180 // Hardness of the workpiece in BHN
// Sample Problem 10 on page no. 221
printf("\n # PROBLEM 4.10 # \n")
lambda = atand(mu)
phi = 45 +alpha-lambda
Fc = f*d*T_s*(cosd(lambda-alpha))/((sind(phi))*(cosd
    (phi+lambda-alpha)))
Fc_ = Fc*(L/1000)
Wav  =Fc_*N/60
t1 = f*cosd(shi)
U_0 = 0.81 // By using table 4.4 given in the book,
    In J/mm^3
Uc = U_0*((t1)^(-.4))
Q = f*d*L*N/60
Wav_ = Uc*Q
printf(" \n Avg power consumption = %d W,\n Specific
     power consumption when hardness of the workpiece
     is 180 BHN = %d W.",Wav,Wav_)
// Answer in the book for Specific power consumption
     is given as 294 W
```

Scilab code Exa 4.11 Calculation of normal rake angle

```
clc
// Given that
alpha_b = 6 // Back rake angle in Degree
alpha_s = 10 // Side rake angle in Degree
gama = 7 // Front clearance angle in Degree
gama_ = 7 // Side clearance angle in Degree
Shi = 10 // End cutting edge angle in Degree
shi = 30 // Side cutting edge angle in Degree
r= 0.5 // Nose radius in mm
// Sample Problem 11 on page no. 224
printf("\n # PROBLEM 4.11 # \n")
k = tand(alpha_b) * cosd(shi) - tand(alpha_s) * sind(shi)
printf("\n The value of k=%f,which is near to 0. Hence the case is close to orthogonal one.\n",k)
alpha= atand(((tand(alpha_b) * sind(shi) ) + (tand(alpha_s) * (cosd(shi))))/ (sqrt(1+((tand(alpha_b)*cosd(shi)) - (tand(alpha_s)*sind(shi)))^(2))))
printf(" \n Normal rake angle = %f .",alpha)
```

Scilab code Exa 4.12 Calculation of component of the machining force and feed forc

```
clc
// Given that
alpha_b = 6 // Back rake angle in Degree
alpha_s = 10 // Side rake angle in Degree
gama = 5 // Front clearance angle in Degree
gama_ = 7 // Side clearance angle in Degree
Shi = 10 // End cutting edge angle in Degree
shi = 30 // Side cutting edge angle in Degree
r= 0.55 // Nose radius in mm
```

```
d = 2.5 // Depth of cut in mm
f = 0.125 // Feed in mm/revolution
N = 300 // Rpm of the job
T_S = 400 // Ultimate shear stress of the workpiece
   in N/mm^2
mu = .6 // Cofficient of the friction between the
   tool and the chip
// Sample Problem 12 on page no. 225
printf("\n # PROBLEM 4.12 # \n")
lambda = atand(mu)
alpha= atand(((tand(alpha_b) * sind(shi) ) + (tand(
   alpha_s) * (cosd(shi))))/ (sqrt(1+((tand(alpha_b)
   *cosd(shi)) - (tand(alpha_s)*sind(shi)))^(2))))
phi = 45 + alpha - lambda
t1 = f*cosd(phi)
w = d/cosd(phi)
Fc = w*t1*T_S*(cosd(lambda-alpha))/((sind(phi))*(
   cosd(phi+lambda-alpha)))
Ft = Fc*tand(lambda-alpha)
Ff = Ft*cosd(shi)
Fr = Ft*sind(shi)
printf(" \n Component of the machining force are as
   follows -\n Feed force component = %d N, \n
   Normal thrust force component = %d N.",ceil(Ff),
   ceil(Fr))
```

Scilab code Exa 4.14 Calculation of drilling torque and thrust force

```
clc
// Given that
D = 20 // Nominal diameter of the drill in mm
T_S = 400 // Shear yield stress of work material in
   N/mm^2
```

```
N = 240 // Rpm
f = 0.25 // Feed in mm/revolution
mu = 0.6 // Cofficient of friction
// Sample Problem 14 on page no. 230
printf("\n # PROBLEM 4.14 # \n")
Beta = 118/2 // From the table 4.12 given in the
    book
shi = 30 // From the table 4.12 given in the book
alpha = atand(((2*(D/4)/(D))*tand(shi))/sind(Beta))
t1 = (f/2)*sind(Beta)
w = (D/2)/sind(Beta)
lambda = atand(mu)
phi = 45+alpha-lambda
t1 = f/2
Fc = w*t1*T_S*(cosd(lambda-alpha))/((sind(phi))*(
    cosd(phi+lambda-alpha)))
Ft = w*t1*T_S*(sind(lambda-alpha))/((sind(phi))*(
    cosd(phi+lambda-alpha)))
M = .6*Fc*D/1000
F = 5*Ft*sind(Beta)
printf(" \n The drilling torque = %f N-m, \n Thrust
    force = %d N.",M,F)
// Answer in the book for drilling torque is given
    as 18.2 N-m, and for thrust force is given as
    1500 N
```

Scilab code Exa 4.15 Calculation of power consumption

```
clc
// Given that
w = 20 // Width of the mild steel block in mm
Z = 20 // No of teeth in milling cutter
D = 50 // Diameter of the milling cutter in mm
```

```
alpha = 10 // Radial rake angle in Degree
f = 15 // Feed velocity of the table in mm/min
N =60 // Rpm of the cutter
t = 1 // Depth of cut in mm
mu = 0.5 // Cofficient of friction
T_s = 400 // Shear yield stress in N/mm^2
t_a = 0.0018 // Avg uncut thickness in mm
// Sample Problem 15 on page no. 235
printf("\n # PROBLEM 4.15 # \n")
Beta = asind(2*(t/D))
theta = 2*%pi/Z
t1_max = (2*f/(N*Z))*sqrt(t/D)
lambda = atand(mu)
phi = 45+alpha -lambda
Fc_max = ((w*t1_max*T_s*cosd(lambda-alpha))/((sind(
    phi))*(cosd(45)))
T_max = Fc_max*D/(2*1000)
M_av = (1/2)*(Beta*T_max)/theta
omega = 2*%pi*N/60
U_0 = 1.4 // From the table 4.4 given in the book
Uc_ms = U_0*((t_a)^(-0.4))
R = f*t*w/60
U = Uc_ms * R
printf(" \n Power consumption = %f W.",U)
```

Scilab code Exa 4.16 Calculation of power required

```
clc
// Given that
w = 20 // Width of the mild steel block in mm
Z = 10 // No of teeth in milling cutter
D = 75 // Diameter of the milling cutter in mm
alpha = 10 // Radial rake angle in Degree
```

```
f = 100 // Feed velocity of the table in mm/min
N =60 // Rpm of the cutter
t = 5 // Depth of cut in mm
mu = 0.5 // Coefficient of friction
T_s = 400 // Shear yield stress in N/mm^2
t_a = 0.043 // Avg uncut thickness in mm
// Sample Problem 16 on page no. 238
printf("\n # PROBLEM 4.16 # \n")
Beta = asind(2*(t/D))
theta = 2*%pi/Z
t1_max = (2*f/(N*Z))*sqrt(t/D)
lambda = atand(mu)
phi = 45+alpha -lambda
Fc_max = ((w*t1_max*T_s*cosd(lambda-alpha))/((sind(phi))*(cosd(45)))
T_max = Fc_max*D/(2*1000)
M_av = (1/2)*(Beta*T_max)/theta
omega = 2*%pi*N/60
U_0 = 1.4 // From the table 4.4 given in the book
Uc_ms = U_0*((t_a)^(-0.4))
R = f*t*w/60
U = Uc_ms * R
printf(" \n Power required = %d W.",U)
// Answer in the book for Power required is given as 817 W
```

Scilab code Exa 4.17 Calculation of power required

```
clc
// Given that
B = 20 // Width of the cut in mm
Z = 10 // No of teeth in milling cutter
D = 75 // Diameter of the milling cutter in mm
```

```
alpha = 10 // Radial rake angle in Degree
f = 25 // Feed velocity of the table in mm/min
N =60 // Rpm of the cutter
t = 5 // Depth of cut in mm
mu = 0.5 // Cofficient of friction
T_s = 400 // Shear yield stress in N/mm^2
t_a = 0.043 // Avg uncut thickness in mm
// Sample Problem 17 on page no. 240
printf("\n # PROBLEM 4.17 # \n")
t1_max = 0.01
lambda = 0.28 // From the table 4.13 Given in the book
nu = 1400 // From the table 4.13 Given in the book
t1_av = t1_max/2
P = nu*B*t*f*(10^-4)/(6*((t1_av)^(lambda)))
printf(" \n Power required = %f W.",P)
```

Scilab code Exa 4.18 Calculation of power required

```
clc
// Given that
w = 20 // Width of the mild steel block in mm
Z = 10 // No of teeth in milling cutter
D = 75 // Diameter of the milling cutter in mm
alpha = 10 // Radial rake angle in Degree
f = 25 // Feed velocity of the table in mm/min
N =60 // Rpm of the cutter
t = 5 // Depth of cut in mm
mu = 0.5 // Cofficient of friction
T_s = 400 // Shear yield stress in N/mm^2
t_a = 0.043 // Avg uncut thickness in mm
// Sample Problem 18 on page no. 240
printf("\n # PROBLEM 4.18 # \n")
```

```
R = f*t*w/60
Uc = 3.3 // Specific energy in J/mm^3 from the table
    4.14 Given in the book
U = Uc * R
printf(" \n Power required = %d W.",ceil(U))
```

Scilab code Exa 4.19 Calculation of peak broaching load

```
clc
// Given that
d = 25 // Diameter of circular hole in mm
t = 20 // Thickness of the steel plate in mm
D = 27 // Enlarged diameter of hole in mm
c= 0.08 // Cut per tooth in mm
alpha = 10 // Radial rake angle in Degree
mu = 0.5 // Cofficient of friction
T_s = 400 // Shear yield stress in N/mm^2
// Sample Problem 19 on page no. 241
printf("\n # PROBLEM 4.19 # \n")
lambda=atand(mu)
phi = 45-lambda+alpha
w = %pi*(d+D)/2
Fc = w*c*T_s*(cosd(lambda-alpha))/((sind(phi))*(cosd
   (45)))
s = 1.75*sqrt(t)
F = 3*Fc
printf(" \n Peak broaching load = %d N.",ceil(F))
```

Scilab code Exa 4.20 Calculation of power required

```
clc
// Given that
D = 250 // Diameter of the wheel in mm
N = 2000 // Rpm of the wheel
f =5 // Plung feed rate in mm/min
C = 3 // Surface density of active grain in mm^-2
A = 20*15 // Area of mild steel prismatic bar in mm^2
rg = 15 // In mm^-1
// Sample Problem 20 on page no. 246
printf("\n # PROBLEM 4.20 # \n")
t1 = sqrt(f/(%pi*D*N*C*rg))
U_0 = 1.4 // From the table 4.4 given in the book
Uc= U_0*((t1)^(-.4))
R = A*f/60
P = Uc*R
Fc_ = 60000*(P)/(%pi*D*A*C*N)
printf(" \n Power requirement during plunge grinding of the mild steel primatic bar = %d W.",ceil(P))
// Answer in the book is given as 94 W
```

Scilab code Exa 4.21 Calculation of grinding force

```
clc
// Given that
w = 25 // Width of mild steel block in mm
d= 0.05 // Depth of cut in mm
D = 200 // Diameter of the wheel in mm
N = 3000 // Rpm of the wheel
f =100 // Feed velocity of table in mm/min
C = 3 // No of grits in mm^-2
rg = 15 // In mm^-1
// Sample Problem 21 on page no. 248
```

```
printf("\n # PROBLEM 4.21 # \n")
t1_max = sqrt(((6*f)/(%pi*D*N*C*rg))*sqrt(d/D))
t1_a = t1_max/2
U_0 = 1.4 // From the table 4.4 given in the book
Uc= U_0*((t1_a)^(-.4))
R = w*d*f/60
P = Uc*R
Fc = 60000*(P)/(%pi*D*N)
printf(" \n Grinding force = %d N",Fc)
```

Scilab code Exa 4.22 Calculation of required depth of cut and feed

```
clc
// Given that
d= 0.05 // Depth of cut in mm
f =200 // Feed rate in mm/min
theta = 850 // Surface temperature in C
Theta = 700 // Maximum surface temperature of workpiece surface required to maintain in C
// Sample Problem 22 on page no. 251
printf("\n # PROBLEM 4.22 # \n")
K = theta * (f^0.2)/(d^0.9)
r = Theta/K
C = d*f
Dm = (r*C^0.2)^(1/1.1)
fm = C/Dm
printf(" \n Required depth of cut = %f mm,\n Required feed = %d mm/min",Dm,fm)
```

Scilab code Exa 4.24 Calculation of maximum height of unevenness

```
clc
// Given that
shi = 30 // Side cutting edge angle in Degree
lambda = 7 // End cutting edge angle in Degree
r = 0.7 // Nose radius in mm
f = 0.125 // Feed in mm
// Sample Problem 24 on page no. 260
printf("\n # PROBLEM 4.24 # \n")
H_max = f/(tand(shi)+cotd(lambda))
H_max_ = (f^2)/(8*r)
printf(" \n Maximum height of uneveness in first
    tool case = %f mm,\n In second tool case = %f mm"
    ,H_max,H_max_)
```

Scilab code Exa 4.25 Calculation of maximum height of unevenness

```
clc
// Given that
Z = 12 // No of teeth
d = 100 // Diameter of cutter in mm
N = 60 // Rpm of cutter
f = 25 // Table feed in mm/min
// Sample Problem 25 on page no. 262
printf("\n # PROBLEM 4.25 # \n")
H_max = (f^2)/(4*d*(N^2)*(Z^2))
printf(" \n Maximum height of uneveness = %f mm",
    H_max)
```

Scilab code Exa 4.26 Calculation of cutting speed

```
clc
// Given that
n = 0.25 // Value of exponent of time in Taylor's
    tool life equation
C = 75 // Value of constant in Taylor's tool life
    equation
Lc = .15 // Labour cast in $/min
Tc = 2.50 // Total cast of tool in $
t = 2 // Change time for tool in min
// Sample Problem 26 on page no. 268
printf("\n # PROBLEM 4.26 # \n")
x = (C)^(1/n) // Where x = k/(f^(1/n))
v_opt = ((n*x*Lc)/((1-n)*((Lc*t+Tc))))^(n)
printf(" \n Cutting speed that will be lead to
    minimum cast = %f m/min",v_opt)
```

Scilab code Exa 4.27 Calculation of cost

```
clc
// Given that
L = 300 // Length of the bar in mm
d=30 // Diameter of the bar in mm
f_max = 0.25 // Maximum allowable feed in mm/
    revolution
Lc = .25 // Labour and overhead cast in $/min
Tc = 2 // Regrinding cast in $
```

```
t = 1 // Change time for tool in min
C_X = 2.50 // Cast of tool of material X per piece in $
C_Y = 3 // Cast of tool of material Y  per piece in $
n_x = 0.1 // Value of exponent of time in Taylor's tool life equation for material X
n_y = 0.16 // Value of exponent of time in Taylor's tool life equation for material Y
C_x = 30 // Value of constant in Taylor's tool life equation for material X
C_y = 76 // Value of constant in Taylor's tool life equation For material Y
// Sample Problem 27 on page no. 269
printf("\n # PROBLEM 4.27 # \n")
x_x = (C_x)^(1/n_x) // Where x = k/(f^(1/n))
v_opt_x = ((n_x*x_x*Lc)/((1-n_x)*((Lc*t+Tc))))^(n_x)
Rmin_x = C_X+Lc*t+(Lc*%pi*L*d/(1000*f_max*v_opt_x)) + (Lc*t*(%pi*L*d/(1000*x_x)))*(v_opt_x^(1/n_y))*(v_opt_x^-1)*(f_max^-1)+(Tc*((%pi*L*d/(1000*x_x)))*(v_opt_x^(1/n_x))*(v_opt_x^-1)*(f_max^-1))
x_y = (C_y)^(1/n_y) // Where x = k/(f^(1/n))
v_opt_y = ((n_y*x_y*Lc)/((1-n_y)*((Lc*t+Tc))))^(n_y)
Rmin_y = C_Y+Lc*t+(Lc*%pi*L*d/(1000*f_max*v_opt_y)) + (Lc*t*(%pi*L*d/(1000*x_y)))*(v_opt_y^(1/n_y))*(v_opt_y^-1)*(f_max^-1)+(Tc*((%pi*L*d/(1000*x_y)))*(v_opt_y^(1/n_y))*(v_opt_y^-1)*(f_max^-1))
printf(" \n The minimum cast per piece\n When material X is used = %f $,\n When material Y is used = %f $",Rmin_x,Rmin_y)
printf("\n So material Y will be suitable for tool as it has low cast")
```

Scilab code Exa 4.28 Calculation of optimum cutting speed

```
clc
// Given that
n = 0.25 // Value of exponent of time in Taylor's tool life equation
C = 75 // Value of constant in Taylor's tool life equation
Lc = .15 // Labour cast in $/min
Tc = 2.50 // Total cast of tool in $
t = 2 // Change time for tool in min
// Sample Problem 28 on page no. 271
printf("\n # PROBLEM 4.28 # \n")
x = (C)^(1/n) // Where x = k/(f^(1/n))
v_opt = ((n*x)/((1-n)*t))^(n)
printf(" \n Optimum cutting speed for maximum production rate for the job = %f m/min",v_opt)
```

Chapter 5

JOINING PROCESSES

Scilab code Exa 5.1 Calculation of maximum power of the arc

```
clc
// Given that
A = 20 // Value of A in voltage length
    characteristic equation
B = 40 // Value of B in voltage length
    characteristic equation
v= 80 // Open circuit voltage in V
I = 1000 // Short circuit current in amp
// Sample Problem 1 on page no. 285
printf("\n # PROBLEM 5.1 # \n")
l=poly(0,"l")
i = ((v-A)-(B* l))*(I/v)
V = (A+B*l)// Given in the question
P = V*i
k = derivat(P)
L=roots(k)
Pmax=((v-A)-(B* L))*(I/v)*(A+B*L)
printf("\n Maximum power of the arc = %d kVA",Pmax
    /1000)
```

Scilab code Exa 5.2 Calculation of rate of heat generated per unit area

```
clc
// Given that
N  =25 // No. of bridges per cm^2
r = 0.1 // Radius of bridge in mm
rho = 2e-5 // Resistivity of the material in ohm-cm
v= 5 // Applied voltage in V
// Sample Problem 2 on page no. 288
printf("\n # PROBLEM 5.2 # \n")
Rc = 0.85*rho/(N*%pi*r*0.1)
Q = (v^2)/Rc
printf("\n Rate of heat generated per unit area = %e W/cm^2",Q)
// Answer in the book is given as 1.136e5 W/cm^2
```

Scilab code Exa 5.3 Calculation of maximum passible welding speed

```
clc
// Given that
P = 2.5 // Power in kVA
t = 3 // Thickness of steel plate in mm
T = 85 // Percentage of total time when arc is on
alpha = 1.2e-5 // Thermal diffusivity of steel in m^2/sec
k = 43.6 // Thermal conductivity of steel in W/m- C
theta_ = 1530 // Melting point of steel in  C
theta = 30 // Ambient temperature in  C
```

```
gama = 60 // Angle in degree
// Sample Problem  on page no. 292
printf("\n # PROBLEM 5.3 # \n")
C = T/100
Q = C*P*10^3
w = t/sind(gama)
theta_m = theta_ - theta
v_max = (4*alpha/(w*(10^-3)))*((Q/(8*k*theta_m*t
    *(10^-3)))-0.2)
printf("\n Maximum passible welding speed = %f m/sec
    ",v_max)
// Answer in the book is given as 0.0146 m/sec
```

Scilab code Exa 5.4 Calculation of maximum shear stress

```
clc
// Given that
t = 1.2 // Thickness of aluminium sheet in mm
t_ = 0.25 // Adhesive thickness in mm
l = 12 // Overlapped length in mm
E = 703 // Modulus of elastisity in N/mm^2
G = 11.9 // Shear modulus of adhesive in N/mm^2
T_S = 0.6 // Ultimate shear stress in N/mm^2
// Sample Problem 4 on page no. 303
printf("\n # PROBLEM 5.4 # \n")
K = (((l^2)*G)/(2*E*t*t_))^(1/2)
T = T_S/K
printf("\n The maximum shear stress the lap joint
    can withstand = %f N/mm^2",T)
// Answer in the book is given as 0.274 N/mm^2
```

Chapter 6

UNCONVENTIONAL MACHINING PROCESSES

Scilab code Exa 6.1 Calculation of time

```
clc
// Given that
a = 5 // Side of the square hole in mm
t = 4 // Thickness of tungsten plate in mm
d = 0.01 // Diameter of abraisive grains in mm
F = 3.5 // Force for feeding in N
A =25e-3 // Amplitude of tool oscillation in mm
f = 25e3 // Frequency in Hz
Hw = 6900 // Fracture hardness of WC in N/mm^2
// Sample Problem 1 on page no. 332
printf("\n # PROBLEM 6.1 # \n")
Z = (1/2)*(4*a^2)/(%pi*d^2)
lambda = 5
d1 = (d^2)
h_w = (sqrt((8*F*A)/(%pi*Z*d1*Hw*(1+lambda))))
Q = (2/3)*((d1*h_w)^(3/2))*Z*f*%pi
t = (a^2)*t/(Q*60)
printf("\n The approximate time required = %f min",t
   )
```

```
// Answer in the book is given as 13.66 min
```

Scilab code Exa 6.2 Calculation of percentage change in cutting time

```
clc
// Given that
r = 1/3 // Ratio of hardness values of copper and steel
// Sample Problem 2 on page no. 335
printf("\n # PROBLEM 6.2 # \n")
R_Q = (r)^(3/4)
R_t = 1/R_Q
P_R = (1-(1/R_t))*100
printf("\n Percentage change in cutting time when tool is changed from coppper to steel = %d percent(reduction)",P_R)
```

Scilab code Exa 6.3 Calculation of current required

```
clc
// Given that
m = 5 // Romoval rate in cm^3/min
A = 56 // Atomic gram weight in gm
Z = 2 // Valence at which dissolation takes place
D = 7.8 // Density of iron in gm/cm^3
// Sample Problem 3 on page no. 345
printf("\n # PROBLEM 6.3 # \n")
I = (m/60)*(D*Z*96500)/(A)
printf("\n Current required = %d amp",I)
```

Scilab code Exa 6.4 Calculation of removal rate

```
clc
// Given that
I = 1000 // Current in amp
p1 = 72.5 // Percentage(by weight) of Ni in Nimonic
    75 alloy
p2 = 19.5 // Percentage(by weight) of Cr in Nimonic
    75 alloy
p3 = 5 // Percentage(by weight) of Fe in Nimonic 75
    alloy
p4 = 0.4 // Percentage(by weight) of Ti in Nimonic
    75 alloy
p5 = 1 // Percentage(by weight) of Si in Nimonic 75
    alloy
p6 = 1 // Percentage(by weight) of Mn in Nimonic 75
    alloy
p7 = 06 // Percentage(by weight) of Cu in Nimonic 75
    alloy
// Sample Problem 4 on page no. 345
printf("\n # PROBLEM 6.4 # \n")
// From the table 6.3 given in the book
D1 = 8.9 // Density of Ni in g/cm^3
D2 = 7.19 // Density of Cr in g/cm^3
D3 = 7.86 // Density of Fe in g/cm^3
D4 = 4.51 // Density of Ti in g/cm^3
D5 = 2.33 // Density of Si in g/cm^3
D6 = 7.43 // Density of Mn in g/cm^3
D7 = 8.96 // Density of Cu in g/cm^3
A1 = 58.71 // Gram atomic weight of Ni in gm
A2 = 51.99 // Gram atomic weight of Cr in gm
A3 = 55.85 // Gram atomic weight of Fe in gm
```

```
A4 = 47.9 // Gram atomic weight of Ti in gm
A5 = 28.09 // Gram atomic weight of Si in gm
A6 = 54.94 // Gram atomic weight of Mn in gm
A7 = 63.57 // Gram atomic weight of Cu in gm
Z1 = 2 // Valence of dessolation for Ni
Z2 = 2 // Valence of dessolation for Cr
Z3 = 2 // Valence of dessolation for Fe
Z4 = 3 // Valence of dessolation for Ti
Z5 = 4 // Valence of dessolation for Si
Z6 = 2 // Valence of dessolation for Mn
Z7 = 1 // Valence of dessolation for Cu
// Above values are given in table 6.3 in the book
D = 100/((p1/D1)+(p2/D2)+(p3/D3)+(p4/D4)+(p5/D5)+(p6
    /D6)+(p7/D7))
Q = ((0.1035*(10^-2))/D)*(1/((p1*Z1/A1)+(p2*Z2/A2)+(
    p3*Z3/A3)+(p4*Z4/A4)+(p5*Z5/A5)+(p6*Z6/A6)+(p7*Z7
    /A7)))
R = Q*I*60
printf("\n Removal rate = %f cm^3/min",R)
```

Scilab code Exa 6.5 Calculation of equilibrium gap

```
clc
// Given that
V = 10 // DC supply voltage in Volt
k = 0.2 // Conductivity of electrolyte in ohm^-1-cm
    ^-1
f = 0.1 // Feed rate in m/min
Vo = 1.5 // Total overvoltage in Volt
F = 96500 // Faraday constant in coulombs per mole
// Sample Problem 5 on page no. 352
printf("\n # PROBLEM 6.5 # \n")
A = 55.85 // Atomic gram weight of iron in gm
```

```
Z = 2 // Valency of dissolation of iron
rho = 7.86 // Density of iron in gm/cm^3
Yc = k*A*(V-Vo)/(rho*Z*F*(f/60))
printf("\n Equilibrium gap = %f cm",Yc)

// Answer in the book is given as 0.04 cm
```

Scilab code Exa 6.6 Calculation of largest passible feed rate

```
clc
// Given that
S_I1 = 5 // Surface irregulation in micro meter
S_I2 = 8 // Surface irregulation in micro meter
V = 12 // DC supply voltage in Volt
k = 0.2 // Conductivity of electrolyte in ohm^-1-cm^-1
Vo = 1.5 // Total overvoltage in Volt
F = 96500 // Faraday constant in coulombs per mole
// Sample Problem 6 on page no. 353
printf("\n # PROBLEM 6.6 # \n")
Y_min = (S_I1+S_I2)*(10^(-4))
A = 55.85 // Atomic gram weight of iron in gm
Z = 2 // Valency of dissolation of iron
D = 7.86 // Density of iron in gm/cm^3
f_max = (k*A*(V-Vo)/(Z*D*F*Y_min))*60
printf("\n Largest passible feed rate = %f mm/min", f_max*10)
```

Scilab code Exa 6.7 Calculation of total force actin on the tool

```
clc
// Given that
f  = 0.2 // Feed rate in cm/min
l = 2.54 // Length of tool face in cm
w = 2.54 // Width of tool face in cm
T_b = 95 // Boiling temperature of electrolyte in
    C
Nita = 0.876e-3 // Viscosity of electrolyte in kg/m-
    sec
D_e = 1.088 // Density of electrolyte in g/cm^3
c = .997 // Specific heat of electrolyte
V = 10 // DC supply voltage in Volt
k = 0.2 // Conductivity of electrolyte in ohm^-1-cm
    ^-1
T = 35 // Ambient temperature in  C
Vo = 1.5 // Total overvoltage in Volt
F = 96500 // Faraday constant in coulombs per mole
// Sample Problem 7 on page no. 355
printf("\n # PROBLEM 6.7 # \n")
A = 55.85 // Atomic gram weight of iron in gm
Z = 2 // Valency of dissolation of iron
D = 7.86 // Density of iron in gm/cm^3
Ye = k*A*(V-Vo)*60/(D*Z*F*f)
J = k*(V-Vo)/(Ye)
D_T = T_b -T
v = (J^2)*(l)/(k*D_T*D_e*c)
Re = ((D_e*v*2*Ye)/Nita)*(0.1)
p = 0.3164*D_e*(v^2)*l/(4*Ye*(Re^0.25))*(10^-4)
A = l*w
F = p*A*(10^-1)*(1/2)
printf("\n Total force acting on the tool = %d N",F)
// Answer in the book is given as 79 N
```

Scilab code Exa 6.8 Calculation of equation of required tool geometry

```
clc
x = poly(0,"x")
// Given that
y = 10+0.3*x-0.05*x^2//Equation of geometry of workpiece surface
V = 15 // Applied potential in Volt
f  = 0.75 // Feed velocity in cm/min
k = 0.2 // Conductivity of electrolyte in ohm^-1-cm^-1
Vo = 0.67 // Total overvoltage in Volt
F = 96500 // Faraday constant in coulombs per mole
// Sample Problem 8 on page no. 361
printf("\n # PROBLEM 6.8 # \n")
A = 63.57 // Atomic gram weight of copper in gm
Z = 1 // Valency of dissolation of copper
D = 8.96 // Density of copper in gm/cm^3
lambda = k*A*(V-Vo)/(D*Z*F)
r = lambda/(f/(10*60))
Y = 10 + 0.3*(x-(r*((0.3-0.1*x)/(1-0.1*r)))) - 0.05*(x-(r*((0.3-.1*x)/(1-0.1*r))))^2 - r
printf("\n The equation of required tool geometry is :-\n  y  =")
disp(Y)
```

Scilab code Exa 6.9 Calculation of time required to complete drilling operation

```
clc
// Given that
a = 10 // Side length of a square hole in mm
t = 5 // Thickness of low carbon steel plate in mm
R = 50 // Resistance in relaxation circuit in ohm
```

```
C = 10 // Capacitance in relaxation circuit in micro F
V = 200 // Supply voltage in Volt
V_ = 150 // Minimum required voltage for discharge in Volt
// Sample Problem 9 on page no. 378
printf("\n # PROBLEM 6.9 # \n")
E = (1/2)*C*(10^-6)*(V_^2)
tc = R*C*(10^-6)*log(V/(V-V_))
W = (E/tc)*(10^-3)
v = t*a^2
Q = 27.4*(W^(1.54))
T = v/Q
printf("\n The time required to complete the drilling operation = %d min",T)
// Answer in the book is given as 306 min
```

Scilab code Exa 6.10 Calculation of surface roughness

```
clc
// Given that
R = 50 // Resistance in relaxation circuit in ohm
C = 10 // Capacitance in relaxation circuit in micro F
V = 200 // Supply voltage in Volt
V_ = 150 // Minimum required voltage for discharge in Volt
// Sample Problem 10 on page no. 382
printf("\n # PROBLEM 6.10 # \n")
E = (1/2)*C*(10^-6)*(V_^2)
tc = R*C*(10^-6)*log(V/(V-V_))
W = (E/tc)*(10^-3)
Q = 27.4*(W^(1.54))
```

```
Hrms = 1.11*(Q^0.384)
printf("\n Surface roughness = %f micro meter",Hrms)
// Answer in the book is given as 5.16 micro meter
```

Scilab code Exa 6.11 Calculation of speed of cutting

```
clc
// Given that
w = 150 // Width of slot in micro meter
t = 1 // Thickness of tungsten sheet in mm
P = 5 // Power of electron beam in KW
// Sample Problem 11 on page no. 391
printf("\n # PROBLEM 6.11 # \n")
C = 12 // Specific power consumption for tugsten in W/(mm^3/min) from the table 6.7 given in the book
v = (P*(1000)/C)*(1000/(w*t))*(1/600)
printf("\n Speed of cutting = %f cm/sec",v)
```

Scilab code Exa 6.12 Calculation of electron range

```
clc
// Given that
V = 150e3 // Acceleration voltage in V
// Sample Problem 12 on page no. 392
printf("\n # PROBLEM 6.12 # \n")
D = 76e-7 // Density of steel in kg/mm^3
Delta = 2.6*(10^-17)*((V^2)/D)
printf("\n Electron range = %d micro meter",ceil(Delta*(10^3)))
```

Scilab code Exa 6.13 `Calculation of speed of cutting`

```
clc
// Given that
w = 0.015 // Width of slot in cm
t = 1 // Thickness of tungsten sheet in mm
P = 5e3 // Power of electron beam in W
// Sample Problem 13 on page no. 395
printf("\n # PROBLEM 6.13 # \n")
rho_c = 2.71 // Value of volume specific heat for tugsten in J/cm^3
k = 2.15 // Thermal conductivity of tungsten in W/cm-C
T_m = 3400 // Melting temperture in  C
Z = t/10 // In cm
v = (0.1^2)*(P^2)/((T_m^2)*(Z^2)*(k*w*rho_c))
printf("\n Speed of cutting = %f cm/sec",v)
```

Scilab code Exa 6.14 `Calculation of time`

```
clc
// Given that
I = 1e5 // Power intensity of laser beam in W/mm^2
T_m = 3400 // Melting temperture of tungsten in  C
rho_c = 2.71 // Value of volume specific heat for tugsten in J/cm^3
k = 2.15 // Thermal conductivity of tungsten in W/cm-C
```

```
p_a = 10 // Percentage of beam absorbed
// Sample Problem 14 on page no. 399
printf("\n # PROBLEM 6.14 # \n")
alpha = k/rho_c
H = (p_a/100)*(I)*(100)
tm = (%pi/alpha)*((T_m*k)/(2*H))^(2)
printf("\n Time required for the surface to reach the melting point = %f sec",tm)
```

Scilab code Exa 6.15 Calculation of time

```
clc
// Given that
I = 1e5 // Power intensity of laser beam in W/mm^2
d = 200 // Focused diameter of incident beam in micro meter
T_m = 3400 // Melting temperture of tungsten in  C
rho_c = 2.71 // Value of volume specific heat for tugsten in J/cm^3
k = 2.15 // Thermal conductivity of tungsten in W/cm - C
p_a = 10 // Percentage of beam absorbed
// Sample Problem 15 on page no. 400
printf("\n # PROBLEM 6.15 # \n")
H = (p_a/100)*(I)*(100)
alpha = k/rho_c
zeta = 0.5 // Fr0m the standard table
 // By solving the equation T_m = ((2*H)*(sqrt(alpha*tm))/k)*((1/sqrt(%pi))-ierfc(d/(4*sqrt(alpha*tm))))
tm = 1/((200^2)*(zeta^2)*(alpha))
printf("\n Time required for the centre of the circular spot to reach the melting point = %f sec
```

```
",tm)
// Answer in the book is given as 0.00013 sec
```

Scilab code Exa 6.16 Calculation of minimum value of beam power intensity

```
clc
// Given that
d = 200 // Diameter of focussed laser beam in micro meter
T_m = 3400 // Melting temperture of tungsten in  C
k = 2.15 // Thermal conductivity of tungsten in W/cm − C
p_a = 10 // Percentage of beam absorbed
// Sample Problem 16 on page no. 401
printf("\n # PROBLEM 6.16 # \n")
H = 2*k*T_m/(d*10^-4)
I = H/(p_a/100)
printf("\n Minimum value of beam power intensity to achieve the melting = %e W/cm^2",I)
```

Scilab code Exa 6.17 Calculation of time

```
clc
// Given that
I = 1e5 // Power intensity of laser beam in W/mm^2
t = 0.5 // Thickness of tungsten sheet in mm
d = 200 // Drill diameter in micro meter
P = 3e4 // Energy required per unit volume to vapourize tungsten in J/cm^3
```

```
p_e = 10 // Percentage efficiency
T_m = 3400 // Melting temperture of tungsten in  C
k = 2.15 // Thermal conductivity of tungsten in W/cm
    - C
// Sample Problem 17 on page no. 403
printf("\n # PROBLEM 6.17 # \n")
H = (p_e/100)*(I)*(100)
v = H/P
T = t*(0.1)/(v)
printf("\n The time required to drill a through hole
     = %f sec",T)
```

Chapter 7

MANUFACTURING IN TWENTY FIRST CENTURY MICROMACHINING GENERATIVE MANUFACTURING AND SELF ASSEMBLY

Scilab code Exa 7.1 `Calculation of maximum allowable wavelength of the exposing li`

```
clc
// Given that
F = 4e-6 // Maximum feature dimension in meter
t = 5e-6 // Photorist thickness in meter
g = 25e-6 // Allowable gap between the mask and the resist meter
// Sample Problem 1 on page no. 432
printf("\n # PROBLEM 7.1 # \n")
lambda = (F^2)/(t+g)
printf("\n Maximum allowable wavelength of the
```

```
exposing light = %d nm",lambda*(10^9))
```

Scilab code Exa 7.2 Calculation of time required to machine the hole

```
clc
// Given that
d = 5 // Diameter of hole in micro meter
h = 100 // Depth of hole in micro meter
// Sample Problem 2 on page no. 440
printf("\n # PROBLEM 7.2 # \n")
t = 31.58*(d*(exp(h/(60*d))-1))
printf("\n Time required to machine the hole = %f
   min",t)
```

Scilab code Exa 7.3 Calculation of minimum level of exposure of the PMMA surface

```
clc
// Given that
J = 2 // The threshold value of dose in kJ/cm^3
h = 300 // Height in micro meter
// Sample Problem 3 on page no. 448
printf("\n # PROBLEM 7.3 # \n")
J_o = J*(exp(0.1*sqrt(h)))
printf("\n The minimum level of exposure of the PMMA
    surface = %f kJ/cm^3",J_o)
```

Scilab code Exa 7.4 Calculation of time required to develop the PMMA resist

```
clc
// Given that
J_ = 2 // The threshold value of dose in kJ/cm^3
J = 15 // The dose of top surface in kJ/cm^3
x_ = 300 // Depth below the surface in micro meter
// Sample Problem 4 on page no. 4
printf("\n # PROBLEM 7.4 # \n")
function y=f(x),y = 3/((J*(exp(-0.1*sqrt(x))))^(1.6)
    -3),
endfunction
t = intg(0,x_,f)
printf("\n The time required to develop the PMMA
    resist = %d min",t)
```