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```
%MED Project
clc
clear all

%Power and  torque requirements
H = 62; % Power(hp)
w_2 = 1200; %rpm
w_5IDEAL = 155; %rpm
m = sqrt(w_2/w_5IDEAL); %gear ratio
phi = 20; %deg
N2calc = (2/(((1+2*m)*(sind(phi)^2)))*(m+sqrt(m^2
 +(1+2*m)*(sind(phi)^2))));
N2 = 15;
N3calc = m*N2;
w_5calc = ((N2/N3calc)^2)*w_2; %rpm
N3 = 42;
N4 = N2;
N5 = N3;
w_5 = ((N2/N3)^2)*w_2; %rpm
w_34 = (N5/N4)*w_5; %rpm
H_lbf = H*550*60; % ft-lbf/min
T2 = H_lbf/w_2; % ft-lbf
T34 = H_lbf/w_34; % ft-lbf
T5 = H_lbf/w_5; % ft-lbf
e = (N2/N3)^2; %gear ratio

%Gear Specification
Y = 60; % Gearbox heigth(in)
c_w = 1.5; %Clearance + wall thickness(in)
Pmin = (N3+ N2/2 +N5/2 +2)/(Y - c_w); %Diametral Pitch(teeth/in)
P = 3; %Diametral pitch used
d2 = N2/P; %in
d4 = d2; %in
d3 = N3/P; %in
d5 = d3; %in
v23 = pi*d2*w_2/12; %ft/min
v45 = pi*d5*w_5/12; %ft/min
Wt23 = 33000*H/v23; %lbf
Wt45 = 33000*H/v45; %lbf
I = (cosd(phi)*sind(phi)/2)*(m/(1+m));
```

```
%Asssuming Q_v=7 precision for commercial gears
A = 65.1;
B = .731;
k_v45 = ((A + sqrt(v45))/A)^B;
k_v23 = ((A + sqrt(v23))/A)^B;
Fcalc = 4*pi/P;
F23 = 3; %in
F45 = 3; %in
Cpf23 = (F23/(10*d2))-.0375+.0125*F23;
Cpf45 = (F45/(10*d4))-.0375+.0125*F45;
Cma = 0.15;
Cmc = 1;
Cpm = 1;
Ce = 1;
km23 = 1 + Cmc*(Cpf23*Cpm + Cma*Ce);
km45 = 1 + Cmc*(Cpf45*Cpm + Cma*Ce);
Cp = 2300; %psi
ko=1;
ks=ko;
Cf=ko;
J24 = .25;
J35 = .38;
kB = 1;
Yn = .9;
Sh = 1.5;
```

Gear 4

```
sig_c4 = Cp*sqrt((Wt45*ko*k_v45*ks*km45*Cf)/(d4*F45*I)); %Contact
 Stress(psi)
L4 = 20000*60*w_34;
Zncalc4 = 1.4488*(L4^-.023);
Zn4 = .9;
Kr= .658 - .0759*log(1-.95); % 95% reliability
Sccalc4 = (Sh*sig_c4)/(Zn4); %Allowable Contact Stress(psi)
%Steel Grade 2 Carburized and Hardened
Sc4 = 225000; %psi
nc4 = (Sc4*Zn4)/(sig_c4*Kr);
sig_t4 = (Wt45*k_v45*P*km45)/(F45*J24); %Bending Stress(psi)
St4 = 65000;
sig_all4 = St4*Yn/Kr; %eq 9-34
ntGear4 = sig_all4/sig_t4
```

```
ntGear4 =

    2.9835
```

Gear 5

```
sig_c5 = Cp*sqrt((Wt45*ko*k_v45*ks*km45*Cf)/(d4*F45*I)); %Contact
 Stress(psi)
```

```
L5 = 20000*60*w_5;
Zncalc5 = 1.4488*(L5^-.023);
Zn5 = .9;
Sccalc5 = (Sh*sig_c5)/Zn5;
%Steel Grade 2 Carburized and Hardened
Sc5 = 225000;
nc5 = (Sc5*Zn5)/(sig_c5*Kr);
sig_t5 = (Wt45*k_v45*P*km45)/(F45*J35);
St5 = 65000;
sig_all5 = St5*Yn/Kr;
ntGear5 = sig_all5/sig_t5
```

```
ntGear5 =

    4.5350
```

Gear 2

```
sig_c2 = Cp*sqrt((Wt23*ko*k_v23*ks*km23*Cf)/(d4*F23*I));
L2 = 20000*60*w_2;
Zncalc2 = 1.4488*(L2^-.023);
Zn2 = .9;
Sccalc2 = (Sh*sig_c2)/Zn2;
%Steel Grade 1 Flame or induction hardened Type B
Sc2 = 170000;
nc2 = (Sc2*Zn2)/(sig_c2*Kr);
sig_t2 = (Wt23*k_v23*P*km23)/(F23*J24);
St2 = 22000;
sig_all2 = St2*Yn;
ntGear2 = sig_all2/(sig_t2*Kr)
```

```
ntGear2 =

    2.5058
```

Gear 3

```
sig_c3 = Cp*sqrt((Wt23*ko*k_v23*ks*km23*Cf)/(d4*F23*I));
L3 = 20000*60*w_34;
Zncalc3 = 1.4488*(L3^-.023);
Zn3 = .9;
Sccalc3 = (Sh*sig_c3)/Zn3;
%Steel Grade 1 Flame or induction hardened Type B
Sc3 = 170000;
nc3 = (Sc3*Zn3)/(sig_c3*Kr);
sig_t3 = (Wt23*k_v23*P*km23)/(F23*J35);
St3 = 22000;
sig_all3 = St3*Yn;
ntGear3 = sig_all3/(sig_t3*Kr)
```

```
ntGear3 =

    3.8089
```

Shaft Layout

```
%INTERMEDIATE Shaft

syms x
Wr23 = Wt23*tand(phi);
Wr45 = Wt45*tand(phi);
%From VM Diagram for yz and xy plane
MtotC = 8694.08;
MtotB = 2149.5;
Mtot(x) = piecewise(x<3, (MtotB/3)*x, 3<=x<12, (MtotB + ((MtotC-
MtotB)/(12-3))*(x-3)),12<=x<15, MtotC + (-MtotC/(15-12))*(x-12));
%figure
%fplot(Mtot(x))
%axis([0 15 0 9000])
MtotI = double(Mtot(10.5));
%AISI 1045  CD
Sut = 108053; %psi
Sexp = .5*Sut; %psi Sut=<200kpsi
ka = 2.7*((Sut/1000)^-.265);
kbtemp = .9;
ke = .868;
SeAssump = ka*kbtemp*ke*Sexp;
KfI = 1.7;
KfsI = 1.5;
ns = 1.5;

AdI = ((16*ns)/pi);
BdI = ((2*KfI*MtotI)/SeAssump);
CdI = sqrt((3*(KfsI*T34*12)^2))/Sut;
%diameters at I
dcons5I = (AdI * (BdI + CdI))^(1/3);

d5I = 3.0;
d4ILib = d5I*1.2;
d4I = 3.4;
RI = d5I/10;

% Fatigue stress conc. factors @ point I
KtI = 1.6;
qI = 0.87;
KfI = 1 + qI*(KtI - 1); %conc. factor bending

KtsI = 1.38;
qsI = 0.9;
KfsI = 1 + qsI*(KtsI - 1); % conc. factor torsion
```

```
Kb = 0.91*(d5I)^-0.157; %size factor

SeActual = ka * Kb * ke * Sexp;

%Calc. safety factor using Von mises
sigaI = (32 * KfI * MtotI) / (pi * d5I^3);
sigmI = sqrt(3*((16 * KfsI * (T34*12)) / (pi * d5I^3))^2);

nfIntShaftLargestD = 1 / ((sigaI/SeActual) + (sigmI / Sut)) %1.86

%n Yield
SyI = 68167;

nyIntShaftLargestD = SyI / (sigaI + sigmI)

% Keyway at J
MtotJ = double(Mtot(11.5));

KtJ = 2.14;
qJ = 0.7;
KfJ = 1 + qJ*(KtJ - 1) ; %conc. factor bending

KtsJ = 3;
qsJ = 0.78;

KfsJ = 1 + qsJ*(KtsJ - 1); % conc. factor torsion

sigaJ = (32 * KfJ * MtotJ) / (pi * d5I^3);
sigmJ = sqrt(3*((16 * KfsJ * (T34*12)) / (pi * d5I^3))^2);

nfIntShaftKey = 1 / ((sigaJ/SeActual) + (sigmJ / Sut))

%point K (groove)

MtotK = double(Mtot(13.5));

d6K = d5I/1.2;
d6 = 2.6;
% %diameters at K
% % %
%1 / (1 + ((0.246 - (3.08*10^-3)*Sut + (1.51*10^-5)*Sut^2 -
 (2.67*10^-8)*Sut^3))/sqrt(0.01))

KfJ = 5;
sigaK = (32 * KfJ * MtotK) / (pi * d6^3);
nfIntShaftGroove = 1 / ((sigaK/SeActual))

% %Point At H ----------------------------------------------------
%
% %diameters at H
% MtotH = double(Mtot(4.5));
% sigaI = (32 * KfI * MtotH) / (pi * d5I^3);
% nfH = 1 / ((sigaI/SeActual) + (sigmI / Sut))
% nyH = SyI / (sigaI + sigmI)
```

```
%
% % Keyway at G
% MtotG = double(Mtot(3.5));
% sigaG = (32 * KfJ * MtotG) / (pi * d5I^3);
% nfG = 1 / ((sigaG/SeActual) + (sigmJ / Sut))
%
% %point F (groove) left side
%
% MtotF = double(Mtot(1.5));
% sigaF = (32 * KfJ * MtotF) / (pi * d6K^3);
% nfF = 1 / ((sigaF/SeActual))
```

nfIntShaftLargestD =

2.5761

nyIntShaftLargestD =

2.3120

nfIntShaftKey =

1.5504

nfIntShaftGroove =

2.2257

INPUT SHAFT

```
syms y
MtotIN = 2079.18;
Mtot(y) = piecewise(y<=3, (MtotIN/3)*y, 3<y<=6, MtotIN -
 (MtotIN/3)*(y-3));
%figure
%fplot(Mtot(y))
%axis([0 6 0 2100])
MtotA = double(Mtot(4.5));
%AISI 1045  CD
Sut = 90648; %psi
Sexp = .5*Sut; %psi Sut=<200kpsi
ka = 2.7*((Sut/1000)^-.265);
kbtemp = .9;
ke = .868;
SeAssump = ka*kbtemp*ke*Sexp;
KfI = 1.7;
KfsI = 1.5;
ns = 1.5;
```

```
AdB = ((16*ns)/pi);
BdB = ((2*KfI*MtotA)/SeAssump);
CdB = sqrt((3*(KfsI*T2*12)^2))/Sut;
%diameters at B
dconsB = (AdB * (BdB + CdB))^(1/3);
dB = 2.4;

dALib = dB*1.2;
dA = 2.8;
RA = dB/10;


% Fatigue stress conc. factors @ point A
KtA = 1.6;
qA = 0.86;
KfA = 1 + qA*(KtA - 1); %conc. factor bending

KtsA = 1.38;
qsA = 0.90;
KfsA = 1 + qsA*(KtsA - 1); % conc. factor torsion

Kb = 0.91*(dB)^-0.157; %size factor

SeActual = ka * Kb * ke * Sexp;

%Calc. safety factor using Von mises
sigaA = (32 * KfA * MtotA) / (pi * dB^3);
sigmA = sqrt(3*((16 * KfsA * (T2*12)) / (pi * dB^3))^2);

nfInputLargestD = 1 / ((sigaA/SeActual) + (sigmA / Sut))

%n Yield
SyB = 76870;

nyInputLargestD = SyB / (sigaA + sigmA)

% Keyway at A (Gear 2) ----------------------------------------
MtotB = double(Mtot(3));

KtB = 2.14;
qB = 0.76;
KfB = 1 + qB*(KtB - 1) ; %conc. factor bending


KtsB = 3;
qsB = 0.78;

KfsB = 1 + qsB*(KtsB - 1); % conc. factor torsion


sigaB = (32 * KfB * MtotB) / (pi * dB^3);
sigmB = sqrt(3*((16 * KfsB * (T2*12)) / (pi * dB^3))^2);
```

```
nfInputShaftKey = 1 / ((sigaB/SeActual) + (sigmB / Sut))


%point C (groove)

MtotC = double(Mtot(1.5));

dClib = dB/1.2;
dC = 2.0;

KfC = 5;
sigaC = (32 * KfC * MtotC) / (pi * dC^3);

nfInputShaftGroove = 1 / ((sigaC/SeActual))
```

nfInputLargestD =

4.1878

nyInputLargestD =

4.1146

nfInputShaftKey =

2.0801

nfInputShaftGroove =

3.8558

OUTPUTSHAFT

```
syms y
MtotIN = 5821.7;
Mtot(y) = piecewise(y<=3, (MtotIN/3)*y, 3<y<=6, MtotIN -
 (MtotIN/3)*(y-3));
%figure
%fplot(Mtot(y))
%axis([0 6 0 6000])
MtotA = double(Mtot(1.5));
%AISI 1045 CD
Sut = 90648; %psi
Sexp = .5*Sut; %psi Sut=<200kpsi
ka = 2.7*((Sut/1000)^-.265);
kbtemp = .9;
ke = .868;
SeAssump = ka*kbtemp*ke*Sexp;
```

```
KfI = 1.7;
KfsI = 1.5;
ns = 1.5;

AdB = ((16*ns)/pi);
BdB = ((2*KfI*MtotA)/SeAssump);
CdB = sqrt((3*(KfsI*T5*12)^2))/Sut;
%diameters at B
dconsB = (AdB * (BdB + CdB))^(1/3);
dB = 4.188;

dALib = dB*1.2
dA = 4.8;
RA = dB/10;


% Fatigue stress conc. factors @ point A
KtA = 1.6;
qA = 0.86;
KfA = 1 + qA*(KtA - 1); %conc. factor bending

KtsA = 1.38;
qsA = 0.90;
KfsA = 1 + qsA*(KtsA - 1); % conc. factor torsion

Kb = 0.91*(dB)^-0.157; %size factor

SeActual = ka * Kb * ke * Sexp;

%Calc. safety factor using Von mises
sigaA = (32 * KfA * MtotA) / (pi * dB^3);
sigmA = sqrt(3*((16 * KfsA * (T5*12)) / (pi * dB^3))^2);

nfOutputLargestD = 1 / ((sigaA/SeActual) + (sigmA / Sut))

%n Yield
SyB = 76870;

nyOutputLargestD = SyB / (sigaA + sigmA)

% Keyway at A (Gear 2) ----------------------------------------
MtotB = double(Mtot(3));

KtB = 2.14;
qB = 0.76;
KfB = 1 + qB*(KtB - 1) ; %conc. factor bending


KtsB = 3;
qsB = 0.78;

KfsB = 1 + qsB*(KtsB - 1); % conc. factor torsion
```

```
sigaB = (32 * KfB * MtotB) / (pi * dB^3);
sigmB = sqrt(3*((16 * KfsB * (T5*12)) / (pi * dB^3))^2);

nfOutputKey = 1 / ((sigaB/SeActual) + (sigmB / Sut))


%point C (groove)

MtotC = double(Mtot(4.5));

dClib = dB/1.2;
dC = 3.4;

KfC = 5;
sigaC = (32 * KfC * MtotC) / (pi * dC^3);

nfOutputGroove = 1 / ((sigaC/SeActual))
```

```
dALib =

    5.0256


nfOutputLargestD =

    3.2118


nyOutputLargestD =

    2.9048


nfOutputKey =

    1.6435


nfOutputGroove =

    6.1993
```

Bearing Load Capacity

```
%From FBD of all shafts
FDIn = 693.05; %lbf
FDOut = 1940.58; %lbf
FDL = 716.52; %lbf
FDR = 2898.03; %lbf
%Weibull parameters
xo = .02;
```

```
theta = 4.459;
b = 1.483;
a = 10/3; %Roller bearings
af = 1.2;
RD = .95; %95% reliability
v = theta - xo;
u = (1-RD)^(1/b);
den = xo + (u*v);
%Input
Lin = 20000*60*w_2;
xDin = Lin/(1e6);
C10in = af*FDIn*(xDin/den)^(1/a); %lbf
C10inN = C10in*4.448
%Output
Lout = 20000*60*w_5;
xDout = Lout/(1e6);
C10out = af*FDOut*(xDout/den)^(1/a); %lbf
C10outN = C10out*4.448 %N
%Intermediate
%Left
LL = 20000*60*w_34;
xDL = LL/(1e6);
C10L = af*FDL*(xDL/den)^(1/a); %lbf
C10LN = C10L*4.448 %N
%Right
LR = 20000*60*w_34;
xDR = LR/(1e6);
C10R = af*FDR*(xDR/den)^(1/a); %lbf
C10RN = C10R*4.448 %N
```

```
C10inN =

   3.8043e+04


C10outN =

   5.7431e+04


C10LN =

   2.8879e+04


C10RN =

   1.1681e+05
```

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