Created by Oliver Arent Heilmann, 26121093

Contents

Importing 'shear stress depth and maximum values as a function of a/b ratios' Table

```
table = xlsread('/Users/OliverHeilmann/Documents/BallBearingCW1.xlsx');
b_dev_a=table(1,1:6);
MaxShearDepth_dev_b=table(2,1:6);
MaxShear_dev_p0=table(3,1:6);
```

Given Values

```
BallRad=6.35*10^-3;
GrooveRad=6.6*10^-3;
TrackRad=38.9*10^-3;
FRad=700;
z=7;
% Values below as [Steel/Steel,Steel/Diamond,Diamond/Steel,Diamond/Diamond]
setup={'Steel/Steel','Steel/Diamond','Diamond/Steel','Diamond/Diamond'};
YMraceway=[213*10^9,213*10^9,1150*10^9,1150*10^9];
vraceway=[0.29,0.29,0.07,0.07];
YMball=[213*10^9,1150*10^9,213*10^9,1150*10^9];
vball=[0.29,0.07,0.29,0.07];
H=[2.0*10^9,2.0*10^9,2.0*10^9,80*10^9];   % Use lower Hardness value for each condition
```

Calculated Values

Before running the calculations for differing setups of steel and diamond we already know that diamond/diamond is the best. In typical overloading conditions, wear can be seen on both the raceway and ball.

```
% For the Steel/Steel case (case 1) we determine that p0>385 MPa. This
% means the material will transition from elastic deformation to plastic.
for i=1:(numel(YMraceway))
    Rx=((1/BallRad)+(1/-TrackRad))^-1;
    Ry=((1/BallRad)+(1/-GrooveRad))^-1;
    R=((1/Rx)+(1/Ry))^-1;
    P=(5*FRad)/z;
    Ered=(((1-(vraceway(i))^2)/YMraceway(i))+ ...
        ((1-(vball(i)^2))/YMball(i)))^-1;
    E=1.0003+((0.0596*Rx)/Ry);
    k=1.0339*(Ry/Rx)^0.6360;
    a=((3*(k^2)*E*P*R)/(pi*Ered))^(1/3);
    b=((3*E*P*R)/(pi*k*Ered))^(1/3);
    p0=(3*P)/(2*pi*a*b);
    pm=(2*p0)/3;
    type = sprintf('This Setup is for %s:',setup{i});
    disp(type)
    if pm>(0.4*H(i))    %Contact will yield in a fully plastic manner
        X = sprintf('    Warning! The bearing will plastically deform.');
        disp(X)
        X1 = sprintf('    p0=%s GPa\n    pm=%s GPa\n\nTrying a new setup...\n ',p0,pm);
```

```
        disp(X1)
    else                %Applied radial forces area acceptable
        X = sprintf('    Tollerances within limit.\n    p0=%s GPa\n    pm=%s GPa',p0,pm);
        disp(X)
        MaxShear_dev_p0_val=interp1(b_dev_a,MaxShear_dev_p0,b/a);
        MaxShear=MaxShear_dev_p0_val*p0;        %Calculating the Maximum Shear Stress
        MaxShearDepth_dev_b_val=interp1(b_dev_a,MaxShearDepth_dev_b,b/a);
        MaxShearDepth=MaxShearDepth_dev_b_val*b;    %Calculating the Maximum Shear Stress Depth
        X1 = sprintf('    Maximum Shear Force Applied=%s GPa',MaxShear);
        disp(X1)
        X2 = sprintf('    Maximum Shear Force is experienced is at %s mm\n',MaxShearDepth*1000);
        disp(X2)
        break
    end
end
```

```
This Setup is for Steel/Steel:
    Warning! The bearing will plastically deform.
    p0=1.271523e+09 GPa
    pm=8.476817e+08 GPa

Trying a new setup...

This Setup is for Steel/Diamond:
    Warning! The bearing will plastically deform.
    p0=1.786182e+09 GPa
    pm=1.190788e+09 GPa

Trying a new setup...

This Setup is for Diamond/Steel:
    Warning! The bearing will plastically deform.
    p0=1.786182e+09 GPa
    pm=1.190788e+09 GPa

Trying a new setup...

This Setup is for Diamond/Diamond:
    Tollerances within limit.
    p0=3.702745e+09 GPa
    pm=2.468497e+09 GPa
    Maximum Shear Force Applied=1.165844e+09 GPa
    Maximum Shear Force is experienced is at 7.073864e-02 mm
```

Post Calculation Notes

From these calculations we can see that a maximum shear force of 1.165844e+09 GPa is experienced at a depth of 0.07074 mm. In order to stop coating delamination one can either provide an adhesive shear strength greater than the maximum shear and/or make sure the bond interface is far away from the maximum shear depth. The next thing to decide is whether one would want the coating to take the shear force or the bulk material. In our case we know that diamond would resist shear forces more readily than steel so I would suggest that the coating be made thicker than the 'z' value (for instance 3*z). The next thing to consider is whether a safety factor should be applied to the system; the magnitude of this would depend on how its' use (i.e. aero/astrospace vs automotive). Finally, one should consider the manufacturing cost of this ball bearing system. Diamond, as well as being extremely hard is especially difficult to cut into rounded shapes (due to the crystalline lattice structure it has).

Safety Factor & Diamond Coating Thickness

```
SafetyFactor=1.5;           % I chose 1.5 however it could be anything
BondStrength=MaxShear*SafetyFactor;
X = sprintf('Adhesive bond strength with safety factor should be %s GPa',BondStrength);
disp(X)
```

```
CoatingThickness=MaxShearDepth*1000*3;      % 3*z is suitable here
X1 = sprintf('Coating thickness should be %s mm',CoatingThickness);
disp(X1)
```

```
Adhesive bond strength with safety factor should be 1.748766e+09 GPa
Coating thickness should be 2.122159e-01 mm
```

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