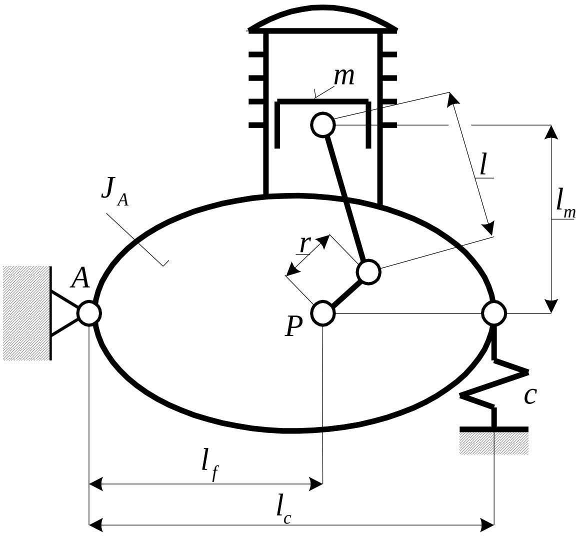
Széchenyi István University
GIVK

Department of
Applied Mechanics

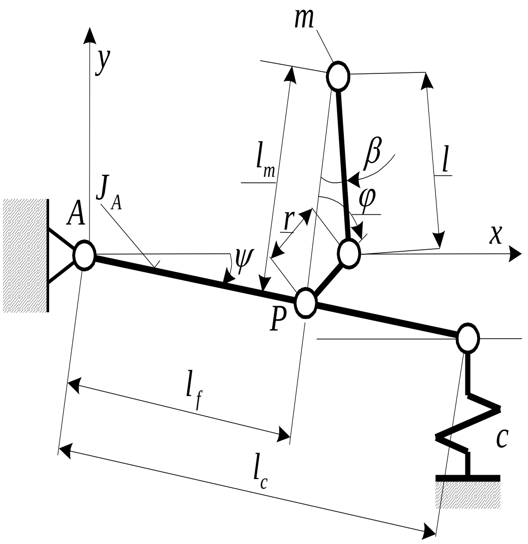
Dynamics of Machines Week 7 – Exercise

scilab-6.0.1
(64-bit)
Desktop

Vibrations of a Single Cylinder Engine with Elastic Mounting



Single Cylinder Engine



Mechanical Model

Equation of motion:

$$\underbrace{\left[J_{Az}+m\left(l_f^2+l^2+\frac{r^2}{2}\right)\right]}_{J_{red}}\ddot{\psi}+\frac{l_c^2\psi}{c}=-ml_f r\Omega^2\cos\Omega t\ ,\qquad \psi=\frac{y_P}{l_f},\ \ \ddot{\psi}=\frac{\ddot{y}_P}{l_f}$$

Rearrangement: $$\ddot{y}_P=-\underset{\alpha^2}{\frac{l_c^2}{c\,J_{red}}}\,y_P-\frac{ml_f^2r}{J_{red}}\Omega^2\cos\Omega t$$

If we take into account damping: $$\ddot{y}_P=-2\alpha\xi\dot{y}_P-\alpha^2y_P-\frac{ml_f^2r}{J_{red}}\Omega^2\cos\Omega t$$

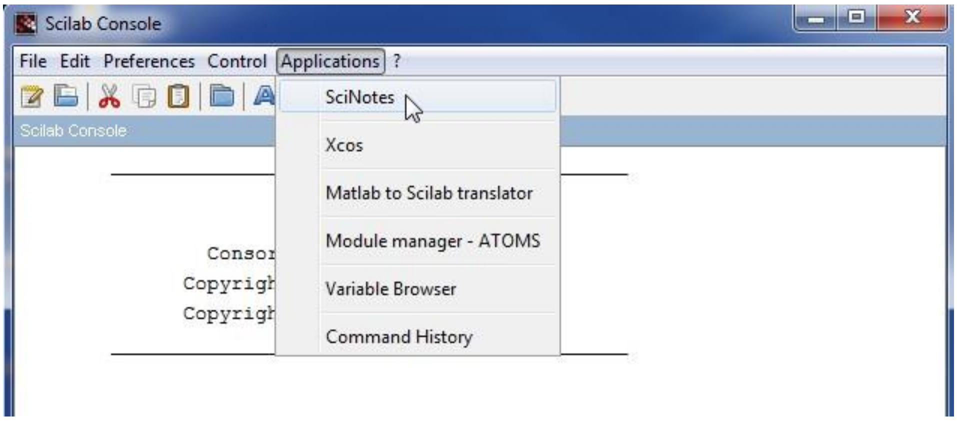
(where $\xi=0{,}1$ is the material damping)

Idle speed of the engine is $n_{\min} = 1000\ ford/min$, maximum engine speed is $n_{\max} = 5000\ \ ford/min$. Determine the spring constant $c\left(m/N\right)$ of the engine mount that the vertical displacement of point P must stay in the $\pm\ 1\ mm$ range in both maximum and minimum engine speed!

There are two spring constants that are the results of previous calculation.

$c_1 = 0{,}00281\ N/m$ (soft spring) and $c_2 = 0{,}000102\ N/m$ (stiffer spring)

Determine which spring is suitable for the engine to fulfill the requirement (±1mm)!



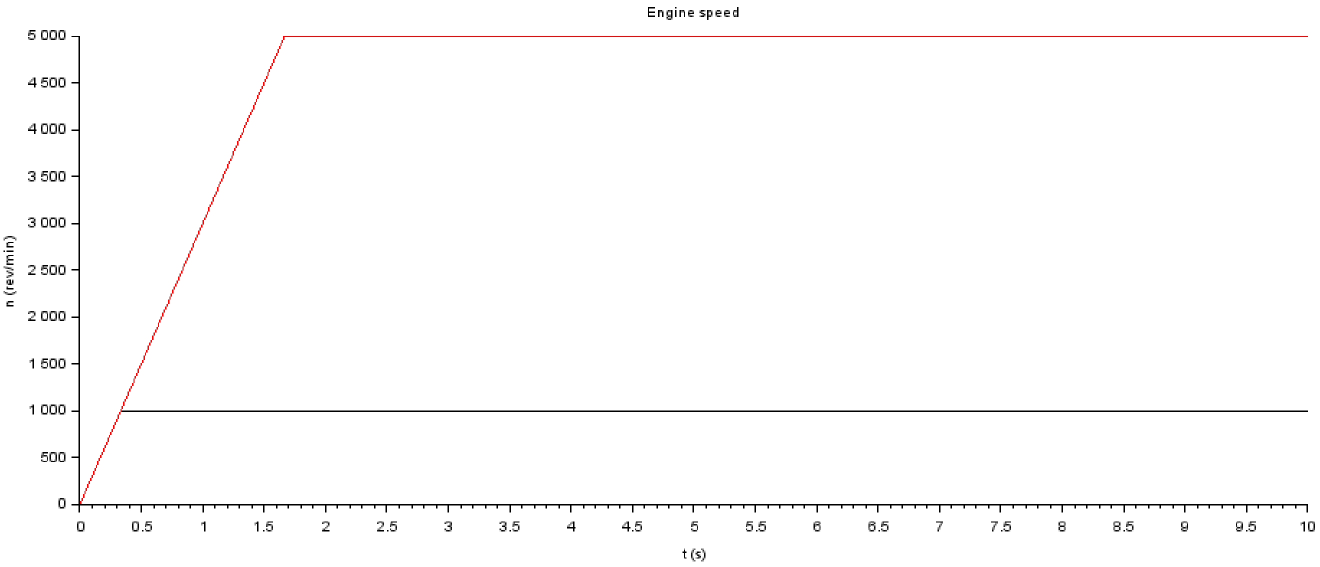
```
// Vibration of a Single Cylinder Engine (omega is variable, Euler method)
clear;
// Variables
lc=0.35;  lf=0.19;            // (m)
r=0.03;                       // crank radius (m)
l=0.12;                       // connecting rod length (m)
Jaz=0.52;                                    // moment of inertia of all parts about z axis (kgm^2)
m_pist=0.5;                                  // piston mass (kg)
Jred_engine=(Jaz+m_pist*(lf^2+l^2+r^2/2));   // reduced moment of inertia about z axis (kgm^2)
Jred_pist=m_pist*(lf^2+l^2+r^2/2);           // reduced moment of inertia of piston about z axis (kgm^2)
// c=0.00281;       // (m/N) spring constant, of the soft spring
c=0.000112;         // (m/N) spring constant of the stiff spring
kszi=0.1;           // Lehr damping coefficient
alf2=lc^2/(c*Jred_engine);
alf=sqrt(alf2);     // (rad/s)  undamped natural frequency
M0=8;               // (Nm)  engine torque
// Engine speed values
n_min=1000;                   // min engine speed (rev/min)
om_min=2*%pi*n_min/60; // min angular velocity (rad/s)
n_max=5000;                   // max engine speed (ford/min)
om_max=2*%pi*n_max/60; //max angular velocity (rad/s)
///////////////////////////////////////////////////////////////////////////////////////////////////////
tmax=10;                      // end time (s)
dt=0.0005;                    // time step (s)
n=int(tmax/dt);               // number of time steps
// Initial values
t0=-dt;                       // (s)
y0=0;                         // (m)
v0=0;                         // (m/s)
a0=0;                         // (m/s^2)
```

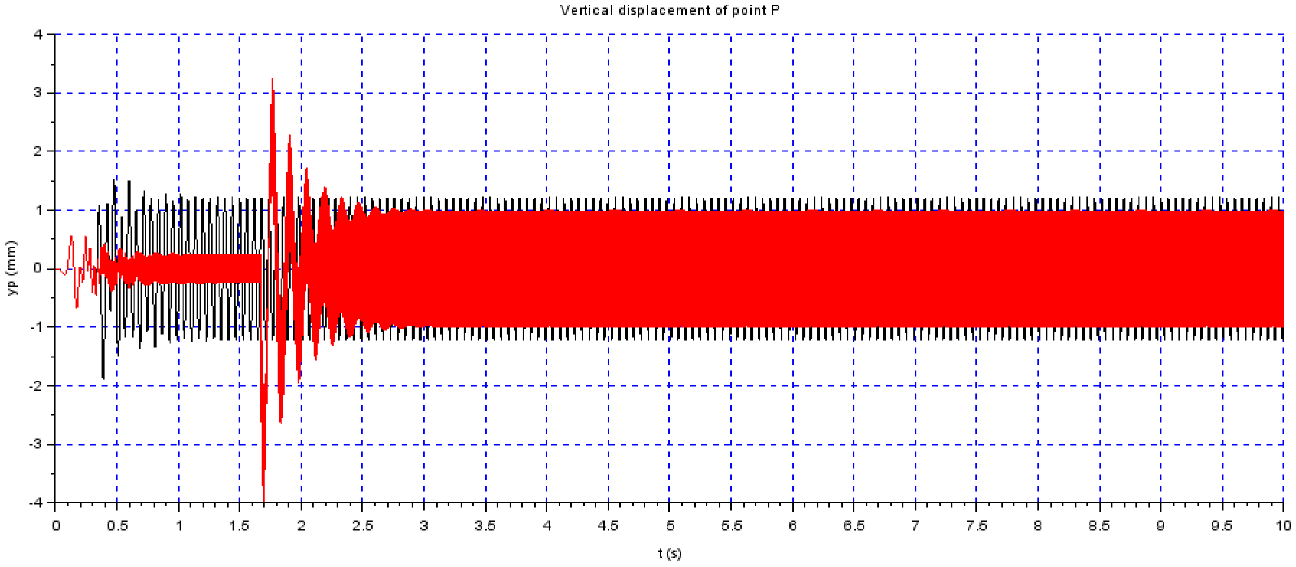
```
omega0=0;                    // (rad/s)
epsz0=M0/Jred_pist;          // (rad/s^2)
a=(1:n);
v=(1:n);
y=(1:n);
om=(1:n);
epsz=(1:n);
/// Calculation /////////////////////////////////////////////////////////////////////////////////////////////////
// Min. engine speed – black color //
for i=1:n
    t(i)=t0+dt;
    epsz(i)=M0/Jred_pist;
    om(i)=omega0+((epsz(i)+epsz0)/2)*dt;

 if om(i)<om_min then
    om1=om(i);
    omeg(i)=om(i);           // It will be plotted
        else
    om1=om_min;
    omeg(i)=om_min;          // It will be plotted
 end
    a(i)=(-2*alf*kszi*v0-alf2*y0-(m_pist*lf^2*r*om1^2/Jred_engine)*cos(om1*t(i)));
    v(i)=v0+((a(i)+a0)/2)*dt;
    y(i)=y0+((v(i)+v0)/2)*dt;
        // Variables value exchange
    t0=t(i);
    v0=v(i);
    y0=y(i);
    a0=a(i);
    omega0=om1;
    epsz0=epsz(i);
end

// Plotting  ////////////////////////////////////////////////////////////////////////////////////
subplot(2,1,1)
plot2d(t,60*omeg/(2*%pi),1)
xtitle("Engine speed"," t (s)","n (rev/min)" )
subplot(2,1,2)
plot2d(t,y*1000,1)
xtitle("Vertical displacement of point P "," t (s)","yp (mm)" )
xgrid(2);

// Copy the script from the initial conditions to the end and paste it below and change some parameters and
variables.

// Max engine speed – red color //////////////////////
t0=-dt;
y0=0;
v0=0;
a0=0;
omega0=0;
epsz0=M0/Jred_pist;
for i=1:n
    t(i)=t0+dt;
```

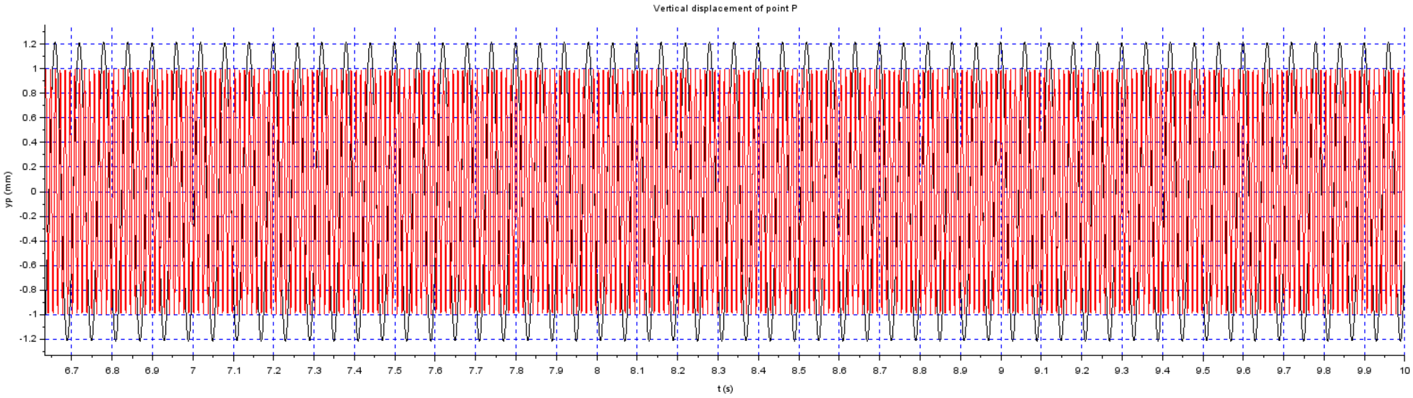
```
    epsz(i)=M0/Jred_pist;
    om(i)=omega0+((epsz(i)+epsz0)/2)*dt;

  if om(i)<om_max then
    om1=om(i);
    omeg(i)=om(i);              // It will be plotted
        else
    om1=om_max;
    omeg(i)=om_max;             // It will be plotted
        end
    a(i)=(-2*alf*kszi*v0-alf2*y0-(m_pist*lf^2*r*om1^2/Jred_engine)*cos(om1*t(i)));
    v(i)=v0+((a(i)+a0)/2)*dt;
    y(i)=y0+((v(i)+v0)/2)*dt;

    t0=t(i);
    v0=v(i);
    y0=y(i);
    a0=a(i);
    omega0=om1;
    epsz0=epsz(i);
end
// Plotting
subplot(2,1,1)
plot2d(t,60*omeg/(2*%pi),5)
xtitle("Engine speed"," t (s)","n (rev/min)" )
subplot(2,1,2)
plot2d(t,y*1000,5)
xtitle("Vertical displacement of point P "," t (s)","yp (mm)" )
xgrid(2);
```

>>>>>> Save the script.

Execute: Execute >>>> .... file with echo





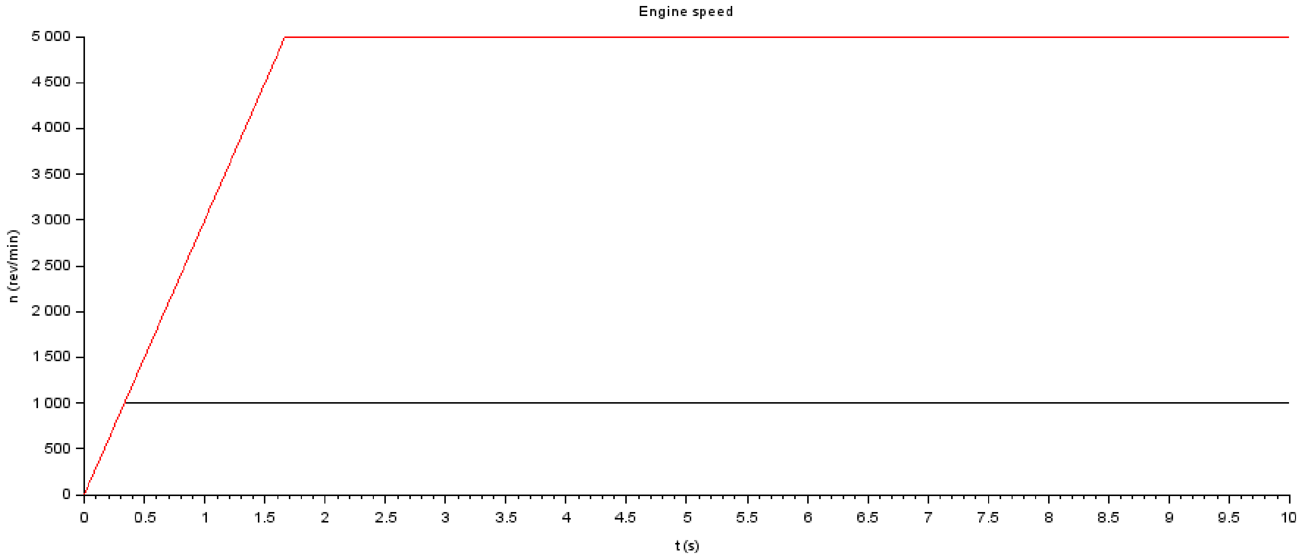


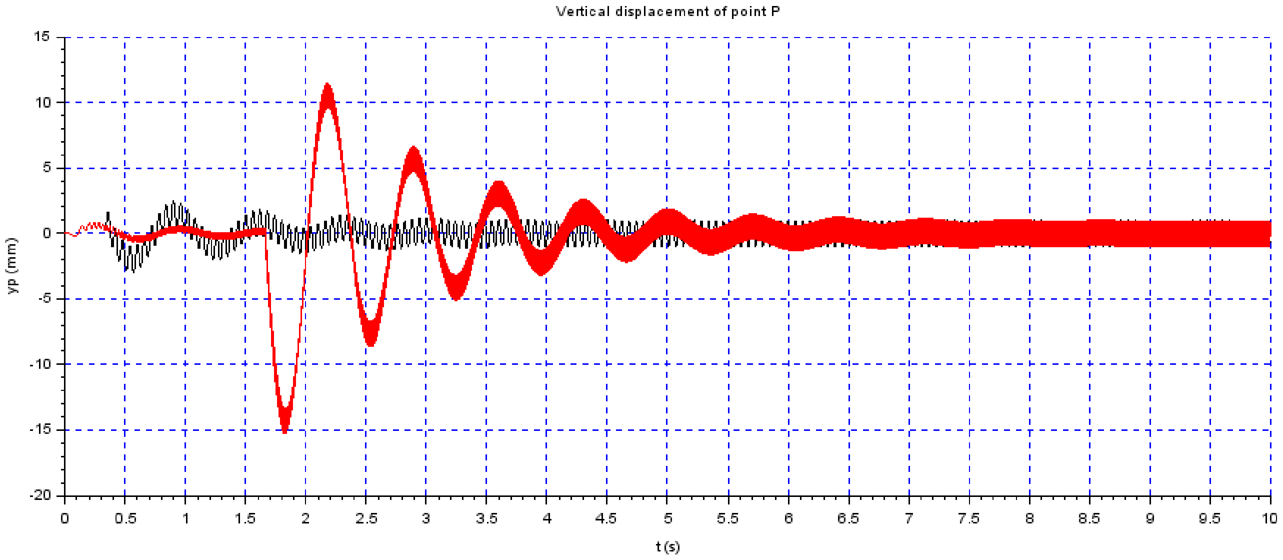
Analyze the steady state vibration after t= 8 s

The stiffer spring is not suitable for the engine because in idle speed the vertical displacement is higher than (+/-) 1mm

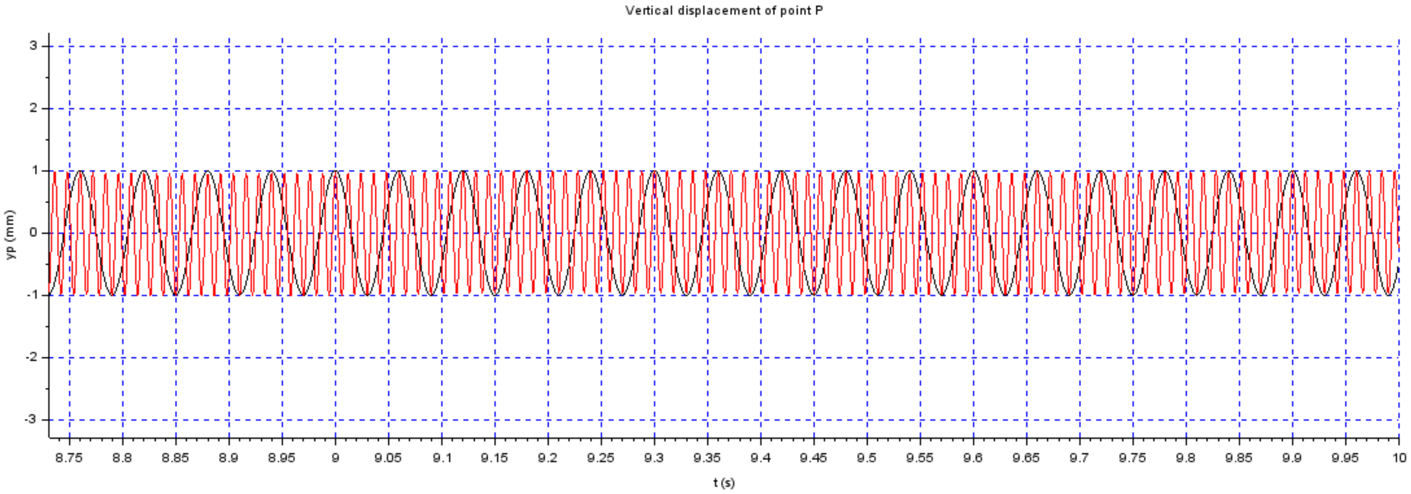
Close the graphic window and change the spring constant to c=0.00281 m/N

Execute (with soft spring): Execute >>>> …. file with echo





Analyze the steady state vibration after t= 8 s



The soft spring is the suitable one because in idle speed and also in maximum engine speed the vertical displacement of point P is in the (+/-) 1mm range.