```
% C. Petersen, H. Werkle, Dynamik der Baukonstruktionen
% 2. Auflage, Springer Vieweg, Wiesbaden, 2018
%
% ML_06_1_Einfreiheitsgradschwinger_mit_nichtlinearer_Kennlinie:
% Schwingungen eines Einfreiheitsgradschwingers mit nichtlinearer Kennlinie
%
% Version 1.0, April 2018
% Softwareentwicklung:
% Andrei Firus, M.Eng (andrei.firus@gmail.com)

% Aufbau Eingabedatei:
%   - Spalte 1: Zeitvektor des Kraftverlaufs [s]
%   - Spalte 2: Kraftvektor [N]
% ANMERKUNG: Dezimaltrennzeichen '.'

% Ausgabedateien:
% Outputdatei_1: Eingaben- und Ergebnisübersicht
% Outputdatei_2: Verschiebungszeitverlauf [m]
% Outputdatei_3: Geschwindigkeitszeitverlauf [m/s]
% Outputdatei_4: Beschleunigungszeitverlauf [m/s^2]

%---------------------------- EINGABEBLOCK --------------------------------
m=5000;                          % Masse des EFS [kg]
d=2500;                          % Dämpfungskoeffizient [Ns/m]

k1=10^6;                         % Lineare Federzahl [N/m]
k2=0;                            % Quadratische Federzahl [N/m^2]
k3=10^8;                         % Kubische Federzahl [N/m^3]
k4=0;                            % Biquadratische Federzahl [N/m^4]

y0=0;                            % Anfangsauslenkung [m]
v0=0;                            % Anfangsgeschwindigkeit [m/s]

dt=0.001;                        % Berechnungszeitschritt [s]

t_ber=10;                        % Gesamtzeit der Berechnung [s]
%--------------------------------------------------------------------------
% Einlesen von Eingabedateien und Generierung der entsprechenden Matrizen
% und Vektoren
Zeitverlauf=dlmread('Inputdatei_1.txt');
t_kraft=Zeitverlauf(:,1);
Kraft=Zeitverlauf(:,2);
%--------------------------------------------------------------------------

%--------------------------- BERECHNUNGSBLOCK-----------------------------
% Berechnung weiterer System- und Berechnungsparameter
nt=ceil(t_ber/dt)+1;             % Anzahl Berechnungszeitschritte
%--------------------------------------------------------------------------
% Interpolation des Kraftvektors mit Berücksichtigung des
% Berechnungzeitschrittes 'dt'
Zeit_Int=0:dt:t_kraft(length(t_kraft));
Kraft_Int = interp1(t_kraft,Kraft,Zeit_Int,'linear');
% ANMERKUNG: Je nach Anwendungsziel kann die Interpolationsmethode geändert
% werden. Für weitere Interpolationsmethoden siehe Matlab-Hilfe zur
% Funktion "interp1" (Befehl 'help interp1' in Command Window)
%--------------------------------------------------------------------------
% Erstellung des Kraftvektors für die Berechnung (einschließlich Ergänzung
```

```
% mit Nullwerten über die Krafteinwirkungsdauer hinaus)

F=zeros(nt,1);
for i=1:1:nt
    if i<=length(Kraft_Int)
        F(i)=Kraft_Int(i);
    else
        F(i)=0;
    end
end
t_b=0:dt:dt*(nt-1);

% ANMERKUNG: Bei Berechnung freier Schwingungen mit Anfangsverschiebung
% bzw. -geschwindigkeit soll die nächste Zeile unkommentiert werden.
% Dadurch werden alle Einträge des Kraftvektors zu Null gesetzt.

% F=zeros(nt,1);

% Berechnung der Schwingungsantwort mittels Differenzenverfahren
y=zeros(nt,1);   % Definition des Verschiebungsvektors
v=zeros(nt-1,1); % Definition des Geschwindigkeitsvektors
a=zeros(nt-1,1); % Definition des Beschleunigungsvektors

% Berücksichtigung der Anfangsbedingungen
y(1)=y0;
v(1)=v0;
a(1)=(F(1)-d*v(1)-(k1*y(1)+k2*y(1)^2+k3*y(1)^3+k4*y(1)^4))/m;

% Schwingweg nach einem Zeitschritt
y(2)=1/2*(2*y0-(dt^2/m)*(k1*y0+k2*y0^2+k3*y0^3+k4*y0^4)+...
    2*(1-d*dt/(2*m))*v0*dt+F(1)*dt^2/m);

% Berechnung der Verschiebungen
for i=3:1:nt
    y(i)=(1/(1+d*dt/(2*m)))*(2*y(i-1)-(dt^2/m)*(k1*y(i-1)+k2*y(i-1)^2+...
        k3*y(i-1)^3+k4*y(i-1)^4)-(1-d*dt/(2*m))*y(i-2)+F(i-1)*dt^2/m);
end

% Berechnung der Geschwindigkeiten
for i=2:1:nt-1
    v(i)=(1/(2*dt))*(y(i+1)-y(i-1));
end

% Berechnung der Beschleunigungen
for i=2:1:nt-1
    a(i)=(1/dt^2)*(y(i+1)-2*y(i)+y(i-1));
end

% Extremwerte
ymax=max(y); ymin=min(y);
vmax=max(v); vmin=min(v);
amax=max(a); amin=min(a);
%--------------------------------------------------------------------------

%------------------------ DARSTELLUNGSBLOCK -----------------------------
%Grafische Darstellung der Ergebnisse
```

```
name_fig1 = 'System und Belastung';
fig1=figure('Name',name_fig1,'NumberTitle','off');
set(fig1,'Position',[1000 50 700 900]);

subplot(2,1,1)
x_f_k_max=0.15;  % x - Achsenlimit für die Darstellung der Federkennlinie
x_f_k=-x_f_k_max:0.01:x_f_k_max;
f_f_k=k1.*x_f_k.^1+k2.*x_f_k.^2+k3.*x_f_k.^3+k4.*x_f_k.^4;
plot(x_f_k,f_f_k,'MarkerSize',3);
title('Federkennlinie');
xlabel('y [m]');
ylabel('f(y) [N]');
grid on; zoom on;

subplot(2,1,2)
plot(t_b,F,'MarkerSize',3);
title('Kraftverlauf');
xlabel('Zeit [s]');
ylabel('Kraft [N]');
grid on; zoom on;
%--------------------------------------------------------------------------
name_fig2 = 'Bewegungszeitverläufe';
fig2=figure('Name',name_fig2,'NumberTitle','off');
set(fig2,'Position',[200 300 800 500]);

subplot(3,1,1)
plot(t_b,y,'MarkerSize',3);
title('Verschiebungszeitverlauf');
xlabel('Zeit [s]');
ylabel('Verschiebung [m]');
grid on; zoom on;

subplot(3,1,2)
t_b_v_a=0:dt:dt*(nt-2);
plot(t_b_v_a,v,'MarkerSize',3);
title('Geschwindigkeitszeitverlauf');
xlabel('Zeit [s]');
ylabel('Geschwindigkeit [m/s]');
grid on; zoom on;

subplot(3,1,3)
plot(t_b_v_a,a,'MarkerSize',3);
title('Beschleunigungszeitverlauf');
xlabel('Zeit [s]');
ylabel('Beschleunigung [m/s^2]');
grid on; zoom on;
%--------------------------------------------------------------------------

%---------------------------- AUSGABEBLOCK --------------------------------
% Ausgabe der Ergebnisse in eine Datei
fid = fopen('Outputdatei_1_Allgemein.txt', 'w');
fprintf(fid,...
    '%s\n','C. Petersen, H. Werkle, Dynamik der Baukonstruktionen');
fprintf(fid,...
    '%s\n','2. Auflage, Springer Vieweg, Wiesbaden, 2018');
fprintf(fid,...
    '%s\n','Softwareentwicklung: Andrei Firus (andrei.firus@gmail.com)');
```

```
fprintf(fid,'%s\n','Programm ML_06_1: Eingaben- und Ergebnisuebersicht');
fprintf(fid, '%s\n', ' ');
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
fprintf(fid,...
    '%s\n','------------------------------------------------------------');
fprintf(fid, '%s\n', ' ');
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
fprintf(fid,...
    '%s\n','EINGABEDATEN:');
fprintf(fid, '%s\n', ' ');
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
fprintf(fid,'%s\n','Masse des Einfreiheitsgradschwingers [kg]:');
fprintf(fid,'%d\n',m);
fprintf(fid, '%s\n', ' ');
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
fprintf(fid,'%s\n','Lineare Federzahl [N/m]:');
fprintf(fid,'%d\n',k1);
fprintf(fid, '%s\n', ' ');
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
fprintf(fid,'%s\n','Quadratische Federzahl [N/m^2]:');
fprintf(fid,'%d\n',k2);
fprintf(fid, '%s\n', ' ');
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
fprintf(fid,'%s\n','Kubische Federzahl [N/m^3]:');
fprintf(fid,'%d\n',k3);
fprintf(fid, '%s\n', ' ');
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
fprintf(fid,'%s\n','Biquadratische Federzahl [N/m^4]:');
fprintf(fid,'%d\n',k4);
fprintf(fid, '%s\n', ' ');
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
fprintf(fid,'%s\n','Daempfungskoeffizient [Ns/m]:');
fprintf(fid,'%.3f\n',d);
fprintf(fid, '%s\n', ' ');
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
fprintf(fid,'%s\n','Anfangsauslenkung [m]:');
fprintf(fid,'%d\n',y0);
fprintf(fid, '%s\n', ' ');
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
fprintf(fid,'%s\n','Anfangsgeschwindigkeit [m/s]:');
fprintf(fid,'%d\n',v0);
fprintf(fid, '%s\n', ' ');
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
fprintf(fid,'%s\n','Berechnungszeitschritt [s]:');
fprintf(fid,'%d\n',dt);
fprintf(fid, '%s\n', ' ');
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
fprintf(fid,'%s\n','Gesamtzeit der Berechnung [s]:');
fprintf(fid,'%d\n',t_ber);
fprintf(fid, '%s\n', ' ');
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
fprintf(fid,'%s\n','Kraftzeitverlauf: siehe Dateiende');
fprintf(fid, '%s\n', ' ');
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
fprintf(fid,...
    '%s\n','------------------------------------------------------------');
fprintf(fid, '%s\n', ' ');
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
```

```
fprintf(fid,...
    '%s\n','ERGEBNISSE:');
fprintf(fid, '%s\n', ' ');
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
fprintf(fid,'%s\n','Maximale Verschiebung [m]:');
fprintf(fid,'%d\n',ymax);
fprintf(fid, '%s\n', ' ');
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
fprintf(fid,'%s\n','Minimale Verschiebung [m]:');
fprintf(fid,'%d\n',ymin);
fprintf(fid, '%s\n', ' ');
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
fprintf(fid,'%s\n','Maximale Geschwindigkeit [m/s]:');
fprintf(fid,'%d\n',vmax);
fprintf(fid, '%s\n', ' ');
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
fprintf(fid,'%s\n','Minimale Geschwindigkeit [m/s]:');
fprintf(fid,'%d\n',vmin);
fprintf(fid, '%s\n', ' ');
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
fprintf(fid,'%s\n','Maximale Beschleunigung [m/s^2]:');
fprintf(fid,'%d\n',amax);
fprintf(fid, '%s\n', ' ');
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
fprintf(fid,'%s\n','Minimale Beschleunigung [m/s^2]:');
fprintf(fid,'%d\n',amin);
fprintf(fid, '%s\n', ' ');
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
fprintf(fid,...
    '%s\n','------------------------------------------------------------');
fprintf(fid, '%s\n', ' ');
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
fprintf(fid,'%s\n','Kraftzeitverlauf:');
fprintf(fid,'%s \t %s\n','Zeit [s]', 'Kraft [N]');
for ii=1:1:length(Kraft)
    fprintf(fid,'%d \t %d\n',t_kraft(ii), Kraft(ii));
end
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
fclose(fid);

%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
Ergebnis_Verschiebungen=[t_b' y];
fid = fopen('Outputdatei_2_Verschiebungen.txt', 'w');
fprintf(fid,...
    '%s\n','C. Petersen, H. Werkle, Dynamik der Baukonstruktionen');
fprintf(fid,...
    '%s\n','2. Auflage, Springer Vieweg, Wiesbaden, 2018');
fprintf(fid,...
    '%s\n','Softwareentwicklung: Andrei Firus (andrei.firus@gmail.com)');
fprintf(fid,'%s\n','Programm ML_06_1: Verschiebungszeitverlauf');
fprintf(fid, '%s\n', ' ');
fprintf(fid,...
    '%s\n','------------------------------------------------------------');
fprintf(fid, '%s\n', ' ');
fprintf(fid,'%s\n','Verschiebungszeitverlauf:');
fprintf(fid,'%s \t %s\n','Zeit [s]', 'Verschiebung [m]');
for ii=1:1:length(y)
    fprintf(fid,'%d \t %d\n',Ergebnis_Verschiebungen(ii,:));
```

```
end
fclose(fid);

%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
Ergebnis_Geschwindigkeiten=[t_b_v_a' v];
fid = fopen('Outputdatei_3_Geschwindigkeiten.txt', 'w');
fprintf(fid,...
    '%s\n','C. Petersen, H. Werkle, Dynamik der Baukonstruktionen');
fprintf(fid,...
    '%s\n','2. Auflage, Springer Vieweg, Wiesbaden, 2018');
fprintf(fid,...
    '%s\n','Softwareentwicklung: Andrei Firus (andrei.firus@gmail.com)');
fprintf(fid,'%s\n','Programm ML_06_1: Geschwindigkeitszeitverlauf');
fprintf(fid, '%s\n', ' ');
fprintf(fid,...
    '%s\n','-------------------------------------------------------------');
fprintf(fid, '%s\n', ' ');
fprintf(fid,'%s\n','Geschwindigkeitszeitverlauf:');
fprintf(fid,'%s \t %s\n','Zeit [s]', 'Geschwindigkeit [m/s]');
for ii=1:1:length(v)
    fprintf(fid,'%d \t %d\n',Ergebnis_Geschwindigkeiten(ii,:));
end
fclose(fid);
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%

Ergebnis_Beschleunigung=[t_b_v_a' a];
fid = fopen('Outputdatei_4_Beschleunigungen.txt', 'w');
fprintf(fid,...
    '%s\n','C. Petersen, H. Werkle, Dynamik der Baukonstruktionen');
fprintf(fid,...
    '%s\n','2. Auflage, Springer Vieweg, Wiesbaden, 2018');
fprintf(fid,...
    '%s\n','Softwareentwicklung: Andrei Firus (andrei.firus@gmail.com)');
fprintf(fid,'%s\n','Programm ML_06_1: Beschleunigungszeitverlauf');
fprintf(fid, '%s\n', ' ');
fprintf(fid,...
    '%s\n','-------------------------------------------------------------');
fprintf(fid, '%s\n', ' ');
fprintf(fid,'%s\n','Beschleunigungszeitverlauf:');
fprintf(fid,'%s \t %s\n','Zeit [s]', 'Beschleunigung [m/s^2]');
for ii=1:1:length(a)
    fprintf(fid,'%d \t %d\n',Ergebnis_Beschleunigung(ii,:));
end
fclose(fid);
%-------------------------------------------------------------------------
```